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BIOGRAPHICAL MEMOIRS

VOL. VIII.

CITY OF WASHINGTON
PUBLISHED BY THE NATIONAL ACADEMY OF SCIENCES
1919



Handwritten scribbles or signatures.

WASHINGTON, D. C.
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PREFACE

In accordance with a rule of the National Academy of Sciences, it is the duty of the President, upon the death of a member, to select some one to prepare a biographical memoir of the deceased.

Such memoirs have been collected in permanent form from time to time for the use of the Academy and for distribution among reference libraries in this country and in Europe. Each biography is supplemented by a list of the scientific publications of the deceased member, and is accompanied by a likeness and a facsimile of his signature, except for the omission of a bibliography in the memoir of John H. C. Coffin; Henry Morton, a list of whose published works forms a part of the Morton Memorial Volume issued by the Stevens Institute of Technology; and that of Miers Fisher Longstreth, whose work was recorded by others.

This volume is the eighth in the series of Biographical Memoirs of the National Academy of Sciences of the United States of America and contains fourteen memoirs, all of which have been issued in separate form. With the close of this volume, one hundred and twenty-two biographies have been published.

CHARLES G. ABBOT,
Home Secretary.

WASHINGTON, *August 1, 1919.*

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J. M. C. Coffin

NATIONAL ACADEMY OF SCIENCES
BIOGRAPHICAL MEMOIRS
PART OF VOLUME VIII

BIOGRAPHICAL MEMOIR

OF

JOHN HUNTINGTON CRANE COFFIN
1815-1890

BY

GEORGE C. COMSTOCK

PRESENTED TO THE ACADEMY AT THE ANNUAL MEETING, 1913

CITY OF WASHINGTON
PUBLISHED BY THE NATIONAL ACADEMY OF SCIENCES
December, 1913

JOHN HUNTINGTON CRANE COFFIN.

"Man goeth to his long home and the place that hath known him shall know him no more." With amendment to the present tense, the words of the Hebrew prophet may fairly be applied to our deceased colleague, Prof. John Huntington Crane Coffin, U. S. N., who a generation ago played a conspicuous part in scientific and official circles, but whose biographical memoir is now to be prepared by one who never saw him, from scanty material furnished by the fading recollections of surviving friends, most of whom in substance join in the words of one of their number, "The more earnestly I have tried to recall incidents or definite data connected with Professor Coffin's life * * * the more I am astonished at my small stock of knowledge in that direction." It is indeed matter of tradition that Coffin prepared somewhat elaborate autobiographical material that, after his death, was intrusted to a friend for use; but the friend has long since passed away and the material now appears to be hopelessly lost.

From independent sources, however, we learn that the Coffins were a seafaring folk long established in Nantucket and traditionally derived from a distinguished English ancestry whose broken links may perhaps be traced back as far as the Wars of the Roses.

An offshoot of this family betook himself in the seventeenth century to the woods of the north New England coast, now a part of the State of Maine, where his descendants served their time and place as professional men, practitioners of civic righteousness, as well as of law and medicine, until in the fulness of time one of these—Nathanael Coffin—took unto himself as a bride Mary Porter, a niece of the Hon. Rufus King, sometime American Minister to Great Britain, and at Wiscasset, Maine, there was born to them, on September 14, 1815, the subject of this memoir—John Coffin.

The earliest details of his life that are now accessible relate to his student days in Bowdoin College, from which he was graduated at the age of nineteen. A classmate, and subsequent

Bowdoin professor, describes him from memory as "of a singularly sweet disposition—affable, gentle, and, as one might say, of fine grain. There was a rare union in him of goodness and genius, to a degree seldom witnessed, accompanied with a modesty that sometimes approaches in appearance to reserve, and yet he was always social and cheerful, much loved by his classmates. We were of the same age, only a month's difference, but especially in the department of mathematics he was years the older of the two. I always looked at him with admiration and pride, feeling that in mathematics he and Hamlin could not be equaled." This reserved geniality of youth was retained by the mature man who is characterized by an official colleague of his later days as "unusually shy and sensitive, not fond of general society—characteristics which sometimes led him to appear almost brusque when it became his duty to speak outside of his circle of intimate associates. He was a pronounced conservative and at times was seriously shocked at the temerity and radicalism of some of the younger and more progressive members of the astronomical contingent in Washington. At the same time he was kindly disposed toward his younger associates and any adverse criticism was generally finished with a smile."

One may fairly say that these two quotations determine the man's inner character and its development as two fixed points determine a right line. The New England lad, of good family and good parts, but born into a narrow environment, developed through a life of untiring industry into a gentleman of the old school, precise and inflexible, a pillar of the church, a conservator of ancient ideals, a worthy member of that remarkable group of students who first commanded esteem for American science.

Immediately following his graduation from Bowdoin the lad sought his remoter family heritage—the sea—through a prolonged sailing trip with his maternal uncle, Capt. King Porter, with whom he commenced those studies of navigation and practical seamanship that thirty years later culminated in his text-book of "Navigation and Nautical Astronomy," long in use at the U. S. Naval Academy as the standard manual of those subjects.

A more immediate consequence of this experience at sea was Coffin's appointment in 1839 as an instructor of midshipmen in the U. S. Navy—a function pursued on shipboard during a period of some five years and frequently supplemented by his discharging the duties of navigating officer and taking part in surveys of the coast. In 1845 the young professor of mathematics was detailed for duty at the National Observatory, Washington, where he reported in October to Lieutenant Maury, then charged with the task of making an astronomical observatory out of material and along lines that are picturesquely described in the earlier volumes of the Washington Observations. It has been the writer's privilege to consult the penciled memoranda entered by Coffin in the margin of his private copy of these volumes and to follow with interest the commentary that they furnish upon the official science of that day. Ranging from frank admission of his own blunders, through mild sarcasm of his surroundings, to sober impeachment of the justice and trustworthiness of his official superiors, they cast a flood of light upon the opinion expressed by a contemporary, "American astronomers should never forget that to him (Coffin) more than any other man is due the credit * * * of saving the Government observatory from destructive ignorance. He laid the foundation for good work, but could not control the superstructure." Coffin was assigned to duty upon the mural circle, an instrument now discredited, but at that time enjoying an excellent repute among astronomers, and his study of this instrument—its capacities, the errors to which it was subject, and the result to be derived with it, as published in the first five volumes of the Washington Observations—constitutes probably his most finished scientific work—a model of painstaking skill and acumen. The excellence of this work is shown by a comparison of its probable errors with those of similar contemporary observations at the Pulkowa Observatory, then esteemed as the unrivaled model of scientific thoroughness and precision. There is little to choose between the American and Russian results. Coffin's official relation to this work, however, was that of a subordinate executing the orders of an omniscient superior, who assumed full responsibility and credit for everything done, even precluding the young professor

from so much initiative as is implied in altering the adjustments of his instrument. This restriction was subsequently withdrawn perhaps in recognition of the young man's quality, but it is sufficiently evident that during his entire connection with the Observatory Coffin chafed under this official impediment cast about his scientific work. In justice to his environment, however, it must be said that its irksomeness was no peculiar quality due solely to naval administration. In some measure even the civilian science of that day put into the relation between senior and junior a feudal character of lord and vassal that would hardly be tolerated now.

The pathetic close of Coffin's career at the Observatory is indicated by a brief note in the volume for 1849, under the date November 7: "Compelled by disease of eyes to desist from observing." He never resumed the work, but was later (1855) transferred to the Naval Academy as head of the Department of Mathematics, and upon Chauvenet's retirement, in 1860, he became also head of the Department of Navigation and Astronomy. Following the outbreak of the Civil War the Naval Academy was prudently removed from Annapolis to Newport, R. I. Its staff of naval officers was largely drawn upon for active service, and Coffin, becoming in effect head of all departments of instruction, bore the brunt of Academy affairs in the stirring years that followed. His modesty stood as the chief barrier to the high credit that should have come to him for his distinguished service, which appears to have received scant official recognition, although it may perchance have been a part of the ground upon which Bowdoin College in 1884 conferred upon him the honorary degree of LL. D. At the close of the war came Coffin's transfer from the Naval Academy to the Nautical Almanac, of which he was made superintendent in 1865 and whose seat he soon shifted from Cambridge to Washington. Although the volume of the American Ephemeris for 1868 bears his name as Superintendent, it was chiefly prepared under his predecessor—Winlock—and Coffin's influence is to be sought in the volumes from 1869 to 1880, inclusive. This influence, although appreciable, cannot be called great. New positions of the standard stars were introduced on more than one occasion and "changes of detail have from time to

JOHN HUNTINGTON CRANE COFFIN—COMSTOCK

time been introduced into the work, but the general plan has remained unaltered." Indeed, the composition of an almanac lends no great scope for originality either of substance or method. By operation of law, Coffin was retired from duty as a naval officer in 1877, and, yielding the superintendency of the Nautical Almanac to Simon Newcomb, he passed his remaining years in retirement, departing this life January 8, 1890.

Much of Coffin's life centers about the Church of the Epiphany at Washington, to whose establishment he was a liberal contributor, of which he was long a vestryman, and within whose walls, in the spring of 1845, he was married to Louisa Harrison, a native of Maryland. Two sons and three daughters were the offspring of this marriage, of whom but one, Mrs. Helen Olcott Paine, now survives (October, 1912).

The abiding memorial of Coffin's scientific career is to be found not in his writings, which are few, but in the three Government bureaus that he served—the Naval Academy, the National Observatory, and the American Ephemeris and Nautical Almanac. Upon the beginning of these several institutions his ideals and his imprint were set, long to remain an influence among his successors, even though they know him not.



Yours cordially
J. M. Owen

NATIONAL ACADEMY OF SCIENCES
BIOGRAPHICAL MEMOIRS
PART OF VOLUME VIII

BIOGRAPHICAL MEMOIR

OF

JOHN WESLEY POWELL

1834-1902

BY

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JOHN WESLEY POWELL.

JOHN WESLEY POWELL was in more senses than one a scientific frontiersman. His life reveals the energetic working of a vigorous and independent personality, not trammled by traditional methods and not so deeply versed in the history, the content, and the technique of the sciences as to be guided by them, but impelled to the rapid discovery of new principles by the inspiration of previously unexplored surroundings. His life shows us further how a man of exceptional power rises suddenly in an otherwise undistinguished lineage, and how he surmounts the limiting associations of early years, less through the opportunity provided by others than through opportunities

Much use has been made of the following articles, especially of the fifth, in which many details of Powell's life are recorded. In a number of cases extracts from these articles are incorporated in the present memoir, with single quotation marks or without marks:

John Wesley Powell, by W. H. Brewer. *Amer. Journ. Sci.*, XIV, 1902, pp. 377-382.

In memory of John Wesley Powell. Minutes of a meeting held at the U. S. National Museum. Edited by S. P. Langley. *Science*, n. s., XVI, 1902, pp. 782-790.

John Wesley Powell, by G. K. Gilbert. *Science*, n. s., XVI, 1902, pp. 561-567, with portrait.

John Wesley Powell, by G. P. Merrill. *Amer. Geol.*, XXXI, 1903, pp. 327-333, with portrait.

John Wesley Powell: A memorial to an American explorer and scholar. Articles by M. D. Lincoln, G. K. Gilbert, Marcus Baker, and Paul Carus. Edited by G. K. Gilbert and published in *The Open Court*. Chicago, 1902-1903.

John Wesley Powell: Proceedings of a meeting commemorative of his distinguished services. *Proc. Washington Acad. Sci.*, V, 1903, pp. 99-130. This contains a portrait, articles by G. K. Gilbert, D. B. Henderson, S. P. Langley, W. J. McGee, C. R. Van Hise, and C. D. Walcott, and a complete bibliography by P. C. Warman.

John Wesley Powell, by C. D. Walcott. 24th Ann. Rept. U. S. Geol. Surv., 1903, pp. 271-287.

John Wesley Powell: A brief review of his career. Epilogue from the "The Romance of the Colorado River," by F. S. Dellenbaugh. New York, 1902, pp. 371-386.

opened by his own individual enterprise for the satisfaction of inborn interests.

EARLY LIFE.

Powell, the fourth of nine children, was born of English parents at Mount Morris, in the Genesee Valley of western New York, on March 24, 1834. His father, Joseph Powell, a Methodist preacher, and his mother, Mary Dean Powell, had come to the United States a short time before. The family moved from New York to Jackson, Ohio, in 1838-1839, to South Grove, Wisconsin, in 1846, and eventually to Illinois, settling first at Bonus Prairie in 1851, and later at Wheaton in 1854; thus in Illinois Powell lived from his seventeenth to his twenty-seventh year.

While he was still a boy in Ohio he had experience of anti-slavery agitation. His father was a staunch abolitionist, who did not conceal his opinions, and as a result the son was so unfairly treated by his mates in the village school that he was removed from it and for a time put under the care of a well-to-do elderly neighbor named Crookham, who taught gratuitously and irregularly in a log-house school and laboratory, as well as in the field. It was thus that young Powell made a beginning in scientific study and observation. When the move was made from Ohio, all the household goods were transported in a wagon and two carriages, one of the latter being driven by young John to Wisconsin. There the boy, when his father was away from home preaching, had the duty of conducting the farm, from which the family derived its principal support, and of hauling farm produce to markets, five or six days to a trip and twelve or more trips in a year; but his heart was in his studies, and in the winter of 1850 he went to Janesville, twenty miles from home, to attend school, working for his keep on a near-by farm.

In 1852 he began school teaching, with half his pupils older than himself; and for the following nine years he alternately taught, studied, and traveled. He had the good fortune at the outset of this laborious period to fall in with intelligent school officials, but much of his teaching was done under narrowing conditions of isolation and privation. His college studies were

varied; they were pursued at Illinois College, Jacksonville, 1855-1856; at Oberlin College, Ohio, 1858, where he studied chiefly botany, Latin, and Greek, and at Wheaton College in 1858. Powell was a naturalist at that time, fond of roaming, observing, and collecting. He had joined the State Society of Natural History in 1854, and in making an extensive collection of mollusca he crossed most of the prairie States. In 1856 he traveled, a young fellow of twenty-two, alone in his boat on the Mississippi; the next year he descended the Ohio, and the year after he followed the Illinois and Des Moines Rivers. His collections brought him into relation with various colleges; he became secretary of the Illinois Society of Natural History, and his friends of that time found him an entertaining narrator, full of enthusiasm, humor, and philosophy.

SERVICE IN THE CIVIL WAR.

Powell's studies and travels were interrupted by the outbreak of the Civil War. A visit to the South on a lecturing tour in 1860, where he closely studied the sentiment of the people regarding slavery, had persuaded him that nothing short of war could settle the matter. When war came he promptly enlisted as a private in the Twentieth Illinois Infantry on May 8, 1861, "with the avowed purpose of doing his part in the extinction of slavery in this country; and from the first day after the call was made for troops he felt thoroughly convinced that American slavery was doomed." He went to the front as sergeant-major, but was soon commissioned second lieutenant. His knowledge of engineering led him into such work as building roads and bridges and planning camps and entrenchments. In the winter of 1861-1862 he recruited a company of artillery, of which he was commissioned captain. A brief leave of absence in March, 1862, allowed him a hurried visit to Detroit, where with only two hours' delay he married his cousin, Miss Emma Dean, to whom he had been long engaged. She returned with him at once to the field, and cared for him not long afterward when he was wounded in the battle of Shiloh, on April 6, 1862. At the moment when he gave a signal to fire by raising his right arm a rifle ball struck his wrist and glanced toward the elbow. The hasty care at first

given to the wound was followed by an operation which left him with a mere stump below the elbow, from which he suffered pain for many years. He was incapacitated at the time for several months; but he later had nearly three more years of active service, during which he was frequently in close relations with General Grant and was commissioned as major of artillery. When finally detailed to act as chief of artillery he had sixteen batteries under his command. Among the busiest days of his life were the thirty or more prior to the fall of Vicksburg, in March, 1864, in part because in addition to his military duties he collected fossils from the trenches. He was honorably discharged January 14, 1865, and, refusing higher rank then offered, was known as "the Major" thereafter. The wound in his arm gave him much pain at various later periods and weakened an exceptionally strong constitution; not until a few years before his death was he fully relieved by a successful operation on the terminating nerves. Some years after the war he met a Confederate officer, Col. C. E. Hooker, who had lost his left arm at Shiloh; the two officers became friends, and when either one in later years bought a pair of gloves he sent the unused glove to his former enemy.

There can be little question that a school teacher of scientific bent, a lone Rambler over prairies, a solitary voyager on long rivers, doing his own work as boatman and collector of natural-history specimens, learned much from the responsibilities placed upon him during four years of soldier's life in the way of reaching prompt decision, giving authoritative command, delegating work to others, and securing loyal obedience from his subordinates. It does not follow that the decisions reached were always the wisest possible, still they were the best available, and action had to be taken on them without hesitating deliberation. But Powell hated war, in spite of his willing service while war lasted; fighting was to him an uncivilized method of dealing with the problems of civilization. He must as an officer have developed many qualities that stood him in good stead as an organizer and administrator in later years; yet it may be well asked whether his faithful perseverance under adverse conditions during nine previous years of study and teaching in a time of peace were not equally decisive in

developing his capacity to carry through whatever he undertook.

VISIT TO THE ROCKY MOUNTAINS, 1867-1868.

The war over, Powell returned to his home in Illinois and was nominated clerk of Du Page County, Illinois, at a good salary; but at the same time he was offered an appointment more to his liking, though at a lower salary, as professor of geology in Illinois Wesleyan College, at Bloomington; this he accepted. A later appointment was that of lecturer and curator of the museum at the Illinois Normal University at Normal, near Bloomington. The young professor took his classes into the field, had an active part in public discussions in favor of introducing more science in college programs, and influenced the State legislature to advance science teaching in the Normal University.

In the summer of 1867 Powell, at the age of thirty-three, struck out on a new path that led to all his later work. Aided by the Illinois Society of Natural History, with which he was still connected, he conducted a party of sixteen "naturalists, students, and amateurs" across the plains to the Rocky Mountains of Colorado, then known more as a field for adventure than for research. His wife accompanied him. Through the aid of General Grant, it was arranged that the army posts should furnish his party with supplies at government rates; railroads gave him passes. A contemplated passage through the Bad Lands under military escort was given up on account of hostile Indians. The expedition visited South and Middle Parks, climbed Pikes Peak and other mountains, and gathered a great store of specimens that were shipped back to the colleges at Bloomington, Normal, and elsewhere. Powell was thus the first college professor to combine field teaching with western exploration, and this enterprise deservedly opened his larger scientific career. He remained in the mountains for a time after his students went home, and in the following winter published a preliminary report, a small affair of four pages, addressed to the Illinois State Board of Education and signed as curator of the Illinois Natural History Society; the only known copy is in the library of the United States Geological Survey.

He returned to Colorado with another party in the summer of 1868, this time with aid from certain colleges in Illinois, and from the Smithsonian Institution in Washington, and again with authority for getting provisions from military posts. He passed the summer in the region of Middle Park. The following winter, Mrs. Powell still being in the party, was spent in camp in the valley of White River, a branch of Green River, in western Colorado and eastern Utah. From this camp Powell made excursions to the Grand, Green, and Yampa Rivers, while thereabouts he made his first studies of Indian tribes and became an ethnologist. There is no indication that he had had earlier training in ethnology, and it may well be believed that it was as largely his warm sympathy as his keen inquiry that led him to eminent success in this field; but the more immediate result of this summer and winter, regarding which no report was published, was his plan for the exploration of the Green-Colorado River by following its course in boats. Perhaps his previous experience on the placid rivers of the prairies led to this adventurous project on a torrential river deeply inclosed in unknown canyons.

EXPLORATION OF THE COLORADO CANYON.

It was truly a daring project. Professor Brewer, of Yale, wrote of it some years later* in effect as follows: Being in Colorado while Powell was making his trip down the river, I was intensely anxious as to his fate, for I thought his project a mad scheme. . . . The river has an average fall of ten or fifteen feet per mile, and I had assumed that there must be great falls, and that the explorer must approach them from above. On telling Powell of this some years later, he answered in substance: "Have you never seen the river? It is the muddiest river you ever saw. Rapids I expected of course, but not falls. I was convinced that the canyon was old enough and the muddy water swift enough and gritty enough to have worn down all falls to mere rapids. I entered the canyon with confidence that I would have no high falls to stop us, although there might be bad rapids, and I believed that we might over-

* Amer. Journ. Science, XIV, 1902, p. 381.

come them in some way—and we did.” The most significant words in this statement are “old enough,” for they show that even before Powell had explored the Colorado he had somehow come to understand that a large muddy river must rapidly acquire a graded course, even though at the bottom of a deep canyon still inclosed by high walls.

Powell returned from the West by rail to Chicago in the spring of 1869 to get boats for the expedition. It was organized as a geographical and geological survey, supported by an appropriation from Congress and placed under the direction of the Smithsonian Institution, of which the then Secretary, Joseph Henry, advised that the collection of ethnological data should be made a leading feature of the journey. The party consisted of ten men. They embarked May 24, 1869, in four boats, where the Union Pacific Railroad crosses the Green River in southwestern Wyoming; followed Green River through deep gorges in the Uinta Mountains to its junction in open country with the Grand River, below which point the name Colorado is given; then continued down the Colorado through its profound canyons in the plateaus of southeastern Utah and northern Arizona to the open country near the Nevada line on August 29. Singularly enough, no sufficient account of this adventurous journey was published until several years afterward, although it attracted much notice at the time. A few brief summaries regarding the canyon and the adjacent region are buried in the congressional documents of the early '70s; but Powell did not at first intend to publish any full report of what he had done and seen. His famous volume, “Exploration of the Colorado River of the West,” 1875, one of the best narratives of adventure anywhere to be found, was not written until four or five years after the event, and then only on the insistence of Representative (later President) Garfield, as Powell tells in 1895 in the preface to his popular book, “The Canyons of the Colorado.” In addition to his report of 1875, several articles were contributed to *Popular Science Monthly* and to *Scribners Magazine* for that year. The country traversed was of exceptional interest and his articles awakened widespread attention. His official report treated the journey in a singularly free and unconventional manner; for

Powell reproduced his original diary, keeping the narrative in the present tense as when written in the canyon, with the result of giving a vivacity to his story unusual in government publications; yet one may read it without learning that the author had lost his right forearm!

The climax of the journey is reached when, after the party had made nearly all the dangerous distance in a little less than three months, three of the men insist that further progress is too perilous, and that the river must be abandoned: they seek a way out by climbing up to the plateau surface. The others persist in following the river, and that very afternoon come upon a group of the most dangerous falls in the whole journey. It is interesting to note that these falls do not constitute an exception to Powell's expectation that the river must have already graded its course in the uplifted rocks of the plateaus, for the obstruction which here caused the falls was formed in an exceptional manner by flows of lava that had, in altogether unpredictable fashion, cascaded down from the volcanoes of the Uinkaret plateau on the north, so recently that they have not yet been cleared away by the river.

As these falls are approached from upstream, there is no possibility of seeing their face and choosing the least dangerous point for descent. The walls are too steep for a portage along the bank; so one of the men, Bradley, approaches the brink of the fall in a boat, held by a tow-line from the cliffs. The current soon becomes so strong that the boat cannot be drawn back; Bradley promptly cuts the line and plunges over the falls, whirling in waves and foam, sinking out of sight, rising again, safe on board and waving his hat. Powell then tells his own manner of descent with two of his men: "We run to the other boat, jump aboard, push out, and away we go over the falls. A wave rolls over us, and our boat is unmanageable. Another great wave strikes us, the boat rolls over, and tumbles and tosses, I know not how. All I know is that Bradley is picking us up. We soon have all right again, and row to the cliff, and wait until Sumner and [W. H.] Powell can come [along the wall]. After a difficult climb they reach us. We run two or three miles farther, and turn again to the northwest, continuing until night, when we have run out of the granite once more." An early start is made the next morn-

ing. "The river still continues swift, but we have no serious difficulty, and at twelve o'clock emerge from the Grand Cañon of the Colorado." Thus simply is it told that on August 29, three months after the start from Green River, the party victoriously passes out of the deep canyon into the open country of the Great Basin. Some of the men go on down the river; Powell went northward through Mormon settlements to Salt Lake City, and thence home. He had been preceded by reports of disaster, and had the pleasure of reading a number of obituary notices of his life.

The good fortune of this daring journey was deservedly of great service to its chief. It developed his capacity for leadership in the field. It received much attention in the newspapers of the time, and thus gave its head a national reputation as a bold, adventurous, successful explorer; best of all, it secured the full confidence of men at Washington who could aid his further work. When in later years of exploration the men of his party gathered around the camp-fire, and the Major talked to them of his passage through the great canyon, "his influence over all his hearers was so profound that in the days that followed a word from him was sufficient to cause the men to go anywhere or to do anything, no matter what the personal danger might be;" and this is no wonder, for he was loyally devoted to his men. Of his companions through the canyon he wrote years afterward: "I was a maimed man; my right arm was gone, and these brave men, these good men, never forgot it."

GEOLOGICAL SURVEY OF THE TERRITORIES.

Powell returned to Utah and Arizona in 1870 and explored the plateaus north of the canyon. A good account of this trip is given in Chapter IX of the "Report on the Colorado River of the West." In 1871 he again made a boat trip on "the river." In 1874 and 1875 he worked chiefly in eastern Utah. Of these three campaigns there is unfortunately no narrative by Powell;* but many of the results are summarized in a re-

* F. S. Dellenbaugh, the youngest member of the latest canyon journey, brought out a belated narrative, "The Romance of the Colorado . . . River," in 1903; he also compiled an account of the earlier journey, "A Canyon Voyage," published in 1908.

markable "Report on the geology of the eastern part of the Uinta Mountains" (1876), published as the work of the second division of the "U. S. Geological and Geographical Survey of the Territories," of which he was then "geologist in charge." His later western journeys, as well as those of the summers of 1872 and 1873, were chiefly occupied with ethnological studies, of which brief accounts are given in Congressional and Smithsonian reports. Powell prepared no other important geological volumes; the great impression that he made on American geology must be credited—apart from his later work as an administrator—to the two reports on the Colorado River and the Uinta Mountains. The popular book on the "Canyons of the Colorado" (Meadville, Pa., 1895) was prepared more than twenty years after the event, and looks more like a publisher's than an author's venture. Several chapters on the native tribes were here included; but the whole appears to have been hastily put together, with too many pictures little related to the text.

REPORT ON THE COLORADO CANYON.

Of the two reports the earlier one on the Colorado is the more important; it is certainly one of the most famous books of exploration published in this country. It is unusually well illustrated, partly with wood cuts from photographs, partly with schematic drawings by Holmes, in some of which a foreground section showing geological structure and a perspective view showing surface form were admirably combined in the style of block diagrams. Powell himself seems to have had no graphic skill, and perhaps for that reason permitted the publication of certain exaggerated pictures, such as that of Horse-shoe Canyon (opposite p. 162), drawn by Moran in a misleadingly realistic fashion; and of a seriously incorrect picture (opposite p. 212), probably drawn from verbal description, of the double unconformity at the bottom of the Grand Canyon, the interpretation of which has puzzled more than one reader, all the more because the excellence of the other illustrations gave reason for thinking that this one also must be trustworthy. The double unconformity is, however, correctly drawn in a geological section of the Uinta Mountains report (p. 43).

Along with the other exploring geologists of that time, Powell enjoyed the inspiring opportunity of working in a new and extraordinary field, where the problems were impressive in magnitude, yet relatively elementary in structure, and all plainly disclosed under the denuding influence of a dry climate. Facts which Nature elsewhere held as her secrets were there openly proclaimed in imposing grandeur. Great series of deposits followed in orderly attitude and almost unbroken sequence; deposition and denudation were measured in tens of thousands of feet; unconformities were superbly exhibited. Deformation had not gone so far as to produce almost unsolvable complications, but had sufficed to cause great faults and flexures of simple pattern, and also to displace huge crustal blocks, with only marginal disturbance, so that the structures of this kind in the Plateau province, first clearly set forth by Powell, became types for the world. The work demanded in detecting the geological history of the region was utterly unlike the detailed and technical investigation given year after year by European observers to the overthrusts of the highlands and the closed folds of the uplands of Scotland or to the overturns of the Alps. Minute studies were not called for in the Plateau country; conclusions were reached rapidly and large concepts were strongly impressed on the observer. It was therefore but natural that Powell's pathfinding geological work should be treated in a style and on a scale prompted by the simplicity and the magnitude of the great structural units with which he had to deal.

Powell used fossils only as guides to the dates of stratified formations, not as a means of making out past forms of life. His volcanic studies were free from complicated nomenclature, guiltless of petrographical technique, and without bearing on the classification of igneous rocks—a subject that was then taking modern shape. He briefly saw and named the Henry Mountains during his canyon trip in 1869, and described them as "composed of eruptive rocks in part" which had been "poured out through some fissures here, and spread over the country before it had been eroded to its present depth" (Colorado River, 177); but his curiosity must have been aroused as to what he did not see, for a few years later he had a special

study made there by Gilbert, whose famous report on the Henry Mountains was thus brought forth. Powell's inattention to the complex structures of crystalline rocks was shown by his usually giving the schists of the fundamental complex at the bottom of the Colorado Canyon the popular name of "granite." He attended relatively little to the conditions under which ancient stratified deposits were accumulated, and probably on this account did not free himself from prepossessions regarding the lacustrine origin of the freshwater Tertiaries, and did not offer any explanation of the extraordinary cross-bedding of the White Cliffs sandstone; but regarding larger structures, he developed broad and bold generalizations that followed immediately from field observation and geological common sense, illumined by a free and lively imagination. He evidently enjoyed the systematization of his results, and repeatedly reduced them to compact schematic form, from which irrelevant details and unknown local names were withheld, greatly to the advantage of his readers. His arguments were usually stated in a simple manner, free from technicalities, and his results were phrased in form for popular understanding. He was fully persuaded that his opinions were correct, and not infrequently stated them in the positive form of "inevitable conclusions," as most of them still seem to be. They carried conviction and are now accepted on nearly all points.

Powell's unconscious style was simple and direct, as in the extract given above describing the end of his passage through the Colorado Canyon, or again in the famous paragraphs cited below regarding the origin of the Green River canyon through the Uinta Mountains. On account of the loss of his right arm he had to employ an amanuensis, and therefore acquired the time-saving capacity of dictating. His reports are astonishingly free from the prolixity that too often accompanies this method of composition; but they occasionally bear marks of insufficient revision in the retention of impromptu inventions like "outthinnings" and in the use of certain words that might to advantage be replaced by others. It was perhaps not unnatural that his phraseology sometimes became exalted, as in the peroration of the Colorado River volume, where, as if recalling the excitement of the canyon journey, he wrote like an

exuberant impressionist: "Then again the restless sea retired, and the golden, purple and black hosts of heaven made missiles of their own misty bodies—balls of hail, flakes of snow, and drops of rain—and when the storm of war came the new rocks fled to the sea" (p. 214).

One of the most marked characteristics of Powell's reports is their freedom from citations of other authors. This was natural enough as far as the description of local features are concerned, for in the regions that he explored he had few geological predecessors, and to those he gives full credit. His citations from the reports of the lamented Marvine are most generous; but in the statement of general schemes of mountain and volcanic structures and of stream and valley classification the case is different. These subjects had been studied in Europe also, and the failure to give due credit to the work of foreign geologists in our Survey reports brought upon us a certain measure of discredit abroad. The reason for inattention to European studies evidently was that our geological frontiersmen found enough in the West to make up the whole of their science; and besides they did not read French and German, and they were so overwhelmed with work that they had no time to spend in looking up prior statements of their newly-perceived principles; so they overlooked foreign work in a continent-wide spirit of North American provincialism.

ANTECEDENT RIVERS.

A significant instance of this kind is found in Powell's famous discussion of the course of the Green River through the Uinta Mountains. He wrote: "The river had the right of way. In other words, it was running ere the mountains were formed; not before the rocks, of which the mountains are composed, were deposited, but before the formations were folded, so as to make a mountain range. . . . The emergence of the fold above the general surface of the country was little or no faster than the general progress of the corrasion of the channel. . . . The river was the saw which cut the mountains in two. . . . The summit of the fold slowly emerged, until the lower beds of sandstone were lifted to the altitude at first occupied by the upper beds, and if these upper

beds had not been carried away they would now be found more than twenty-four thousand feet above the river" (Colorado River, 152, 153). This is an admirable statement of a great idea. It bears not only upon the processes of river evolution, but upon the fundamental principles of geology. It was a welcome reinforcement of the arguments for uniformitarianism, which, though valiantly urged by Hutton, Playfair, and Lyell regarding processes of erosion and deposition, were even later than the middle of the nineteenth century not entirely successful in vanquishing the widespread traditional belief in violent processes of deformation and upheaval. Powell's demonstration, as he thought it, that the Uinta Mountains were not lifted up faster than the Green River could cut its canyon down through their broad anticline had great influence in convincing his contemporaries that uplift as well as erosion and deposition is a slow process, and thus aided, the gentle doctrine of geological peace on earth gained a vast backward extension into periods of the past that had long been conceived as ages of violence.

It was to rivers which, like the Green in the Uintas, had held their course through an area of adverse uplift that Powell gave the excellent name of antecedent. He appears to have made no search whatever to learn whether other observers had come upon the same idea; not that he was in the least disposed to claim priority by neglecting their labors, but that he was fully engrossed in his own. In a thorough review of this problem, Penck* points out that Medlicott in India and Hayden in the United States had both preceded Powell in recognizing the persistence of certain rivers in holding their courses through slowly uplifted mountain ranges. Medlicott† inferred the long persistence of certain rivers and the slow, imperceptible progress of deformation and uplift, because of "marked correspondence between the distribution of the accumulations of conglomerate [ancient piedmont river deposits] and the position of actual river gorges" through the outer ranges of the

* A. Penck. *Die Bildung der Durchbruchstäler*. Verein z. Verbr. naturwiss. Kenntnisse in Wien, 1888.

† H. B. Medlicott. *The Alps and the Himalayas. A geological comparison*. Quart. Journ. Geol. Soc., XXIV, 1868, pp. 34-52.

Himalayas. Some of the upturned conglomerates are "as thick and at as high angles as those on the Righi" in the Alps (46). The Sutlej in particular is instanced as having held its course from a time before the outer or subhimalayan ranges were raised. After issuing from deep valleys in lofty inner ranges it passes through low hills of soft rocks, and then trenches a ridge formed of "massive beds of coarse conglomerate of boulders, such as only occur in the main river channels. These beds are now raised to the vertical, and in both directions along the strike these conglomerates pass gradually within a few miles into the ordinary sandstones. The presumption from such a coincidence seems irresistible, that the Sutlej itself had deposited these banks of boulders at the spot where it still flows" (47).

Hayden's statement, based on studies in Montana, is as follows: "The fact that the streams seem to have cut their way directly through mountain ranges, instead of following synclinal depressions, indicates that they began the process of erosion at the time of the commencement of the elevation of the surface. This is shown all along the valley of the Yellowstone, and more conspicuously in the valleys of the Madison and Gallatin, which have carved immense canyons or gorges directly through two of the loftiest ranges of mountains in Montana. We believe that the course of these streams was marked out at or near the close of the Cretaceous period, and as the ranges of mountains were in process of elevation to their present height the erosion of the channels continued. The details of the observations which contribute to form this opinion would occupy a chapter or two." * Both of these authors, however, treated the problem of persistent rivers in an incidental manner, subordinating it to other larger topics; neither of them gave an elaborate or an emphatic statement to his theory, and neither of them invented a handy and suggestive generic name for the kind of rivers that they explained. The taking term, antecedent, was a forcible supplement to the ex-

* Report of F. V. Hayden, Sixth Ann. Rept. U. S. Geol. Survey of the Territories for 1872. Washington, 1873, p. 85. The paragraph above quoted was foreshadowed in an earlier article. Amer. Journ. Sci., XXXIII, 1862, pp. 68-79.

planation of the profound idea involved in Powell's report; and this may be fairly taken to show that, notwithstanding the adverse opinion often inappropriately quoted to the contrary from the emotional pleading of a charming heroine, there is really matter of much import in a name.

But Powell's further argument in support of the antecedence of Green River through the Uinta Mountains includes, curiously enough, the case of certain streams which follow valleys excavated in belts of weak strata along the flanks of the range. Had the range been suddenly uplifted, these streams should, according to Powell, follow the dip of the strata; as they follow the strike instead of the dip, the uplift must have been gradual. "The direction of the streams is indubitable evidence that the elevation of the fold was so slow as not to divert the streams. . . . Had the fold been uplifted more rapidly, . . . all the smaller streams and waterways should have been cataclinal" (flowing down the dip). Hence "the drainage was established antecedent to the corrugation or displacement of the beds by faulting and folding" (Colorado River, 163). The same argument is used with respect to the drainage lines of the Arizona plateaus: "All the facts concerning the relation of the waterways of this region to the mountains, hills, cañons, and cliffs lead to the inevitable conclusion that the system of drainage was determined antecedent to the faulting and folding and erosion which are observed, and antecedent, also, to the formation of the eruptive beds and cones" (*Ibid.*, 198). Yet the longitudinal valleys, here referred to as so decisive in the discussion of antecedence, are apparently of the kind that had been explained ten years earlier (1862) by Jukes, from his studies of the Blackwater in southern Ireland, as having been slowly developed by headward or retrogressive erosion along the strike of weak beds; thus interpreted, they indicate slow adjustment of streams to structures and probably do not bear on the problems of antecedence at all.

This is not the place for further discussion of Green River, regarding which the theory of superposition suggested by Emmons merits consideration along with Powell's theory of antecedence. It indeed seems possible that Green River, which was described as the type of antecedent rivers when that term

was introduced, may be otherwise explained, so that its place as type will be taken by a better-proved example of antecedence, such as the Meuse in the Ardennes. This fate of a type is, however, not so very rare. The uplands of southern New England, described some twenty years ago as the type of an uplifted and dissected lowland of erosion, for which the name peneplain was then suggested, may, like Green River, have to yield their place to a better-proved example. The object in here pointing out the invalidity of Powell's argument is to show that even when a mind as original and powerful as his works in a field as inspiring as that of the Uinta Mountains, trenched by the canyon of the Green River, there is danger in overlooking, as Powell too often did, the work of earlier investigators on similar problems. It would be no more fitting to omit mention of this characteristic shortcoming of method from an account of Powell's work than to paint out a wrinkle in a true picture of his rugged and kindly face. But in any case, whether the Green River followed its present course antecedent to the uplift of the Uintas or not, and whether any other geologist preceded Powell in recognizing the occurrence elsewhere of rivers of this origin, it is distinctly to Powell that geology now owes the general acceptance of the idea of antecedence in river development.

GEOLOGICAL WORK.

Powell's contribution to geology—apart from the action of surface processes and the explanation of surface forms—related chiefly to large structural problems. He published many carefully studied columnar sections, giving indication of thickness, composition, and unconformities, and making provisional assignment of geological dates; but on the latter point he wisely held that "it would be manifestly absurd to introduce into a newly studied province the nomenclature which had been adopted in those provinces previously studied" (Uinta, 38). This principle guided him some years later, when he pointed out in his first report as Director of the United States Geological Survey that the introduction of local formation names has taken place "in opposition to received opinions, and in spite of the almost universal efforts of geologists to attain uni-

formity; *it therefore represents the logical and necessary growth of the science.* . . . It seems especially unwise for the exploring geologist to commit himself in early stages of investigation to refined and exact correlations, and in practice it is found that a great number of local names are used tentatively until further research demonstrates approximate identity or establishes diversity."

Powell was one of the pioneers in the demonstration of the almost undisturbed continuity of deposition in the West from Cambrian to Tertiary time, sometimes slightly interrupted by gentle unconformities, but without trace of the "revolution" that, from the structures known in Europe and eastern North America, had been previously supposed to mark a world-wide break between the depositional records of Paleozoic and Mesozoic times. He was the first to bring out the great structural features of the Plateau province, already referred to. He repeatedly emphasized the action of uplifting rather than of compressing forces, for he had chiefly to do with broad structures of nearly horizontal strata, limited by faults or, as he so justly remarks, their homologues, monoclinical flexures; and the latter style of deformation was in his time a geological novelty. Complicated deformation was mostly limited in the Plateau region to "zones of diverse displacement" between extended areas of little disturbance; the only sharp folds with which he had to do occurred in these narrow zones. He suggested that flexing of strata was probably a deep-seated process, while faulting was a more superficial one. As in his discussion of the problem of antecedence, stated above, so through all his writings, he strongly supported the then growing idea that "upheaval was not marked by a great convulsion, for the lifting of the rocks [in the Uintas] was so slow that the rains removed the sandstones almost as fast as they came up."

Following his systematic habit of mind, he grouped the mountainous reliefs of his region into two great classes; some were composed of sedimentary strata and others of extravasated materials. He then divided these classes into a number of types according to details of structure, and subdivided them still further according to the work of erosion upon them. The Appalachians were the only mountains here mentioned

outside of his own field. The names given to his types were usually taken from local examples, although in certain cases similar structures had long been well known in other fields. His reason for thus passing over the earlier work of others elsewhere was evidently that he wished simply to classify the phenomena that he had himself observed. It was perhaps by reason of the habit of reducing his facts to schematic arrangement that he gave an oversimplified account of the Basin ranges. He did not explicitly announce that the prefaulting mass in the Great Basin was of complicated structure and possibly of irregular surface; he indeed tacitly implied a horizontal structure and plain surface when he wrote: "When the blocks into which a district of country has been broken by faults are greatly tilted, so that the strata dip at high angles, the uplifted edges of such blocks often form long mountain ridges. . . . Many of the ridge-like mountains of the Basin province have this structure. Such a ridge is composed of monoclinical strata, the one side presenting a bold escarped front, the other a more gently sloped back conforming to a greater or less degree with the dip" (Uinta Mountains, 16). It is possible that the failure of later observers to find simple monoclinical structures and forms in the Basin ranges corresponding to this simple description is in part responsible for the misunderstandings that have arisen regarding the origin of the ranges. In another connection Powell's account of the Basin ranges is more satisfactory, as will appear below.

PHYSIOGRAPHIC WORK.

Powell's contribution to the discussion of erosional processes and their effect in the development of land forms was of fully as great value as his more strictly geological studies, and certainly exerted a marked influence on the work of later students of physiographic problems. It is not too much to say that in this division of his studies he, with his able collaborators, laid the foundations of what may be fairly called the American school of geomorphology, now eagerly embraced by modern physiographers everywhere, and that he thus contributed immensely to the awakening and the advance of the sluggish old science of geography. It is worth pointing out

that a physiographic turn was given to Powell's work, not so much from his own intentional preference or selection, but from the abundant and open opportunity for physiographic study in a semi-arid region, for, in common with nearly all the early geological explorers of the West, Powell was led by his environment to give much attention to surface forms; he could not fail to see their intimate relation to internal structure, so wonderfully displayed by reason of the scantiness or absence of vegetation. He therefore inevitably described the relief of his region by explaining it, and his explanation was presented in terms of structural masses, raised by internal diastrophic forces and worked upon by external destructive forces. He emphasized internal or "geological" structure as the prime basis for the classification of land forms, and adopted as the guide to their secondary grouping the erosion of what he called "concomitant," or, as would now be said, sequential, minor forms. He did not explicitly make the next step of systematically describing the stages in the progress of erosion during its work upon uplifted masses, but it must be a careless reader who does not repeatedly find this principle implied in a careful study of Powell's writings. At this time, as well as later, Powell had the great advantage of discussing his problems with a younger investigator of the Cordilleran region, whose sound views probably had a larger influence in shaping his senior's opinions than will ever be directly known.

As to the action of erosional processes, Powell's reports abound in quotable statements, of which the following are good examples: "Erosion is not greatly promoted by increased rainfall. . . . With greater rainfall we have greater power, but a lesser utilization of the power; with lesser rainfall we have lesser power, but greater utilization; and in these varying conditions, just where maximum degradation is found I am not able to state." "I have many times witnessed the action of a storm in an arid region where the disintegrated rocks were unprotected by forests, shrubbery, or turf, and as often have I been impressed with the wonderful power of the infrequent storm to gather up and carry away the land, as compared with the frequent storm in the prairie or forest of a land more richly clad" (Uinta, 188; see also Colorado River, 171).

Attention to stream action naturally led to an attempt to classify streams and valleys. Two classifications were proposed; the first was based on the relation of streams to the strata that they traversed; several types were admirably illustrated in ideal figures drawn by Holmes, and each type was given a name of Greek origin, as cataclinal, diacinal, and so on; but these names have not come into general use, perhaps because they express only an empirical relation. The second classification of streams and valleys was in terms of their origin; the three kinds here recognized were given names of Latin derivation—antecedent, consequent, and superimposed—last two kinds having been recognized but not named by Marvin, from whom Powell quotes; and these names have come into general use among modern physiographers. River behavior was discussed with much originality, and reasonable meaning was given to features that had previously been stated empirically; for example: "In the Colorado river, with very few exceptions, all the falls and rapids which beset its course through the great cañons are caused by dams of boulders made by side streams having great declivity" (Uinta, 193). Regarding Platte River, on the plains, it is luminously stated: "The beds through which the river runs are incoherent, and although the river has as great a fall as the Colorado through the plateaus, and although the climatic conditions are essentially the same, yet the former runs in a broad sheet scarcely below the level of the plain, while the latter runs in a narrow groove at profound depths below the general surface" (Uinta, 194). The nature and amount of river load and the manner of its transportation are carefully considered. The load "does not float on the water, but behaves as an integral part of it, and with it obeys the laws of hydrodynamics" (Uinta, 184). The principles here announced were afterwards developed with greater fullness in an address before the National Academy of Sciences, under the title of "The laws of hydraulic degradation," with the object of mentioning "the principal efficient methods of controlling rivers in their floodplain reaches;" and here Powell's indifference to precedent is shown again, for although the problem and the technique of river control have been abundantly discussed and successfully practiced in

Europe, Powell's published paper (*Science*, XII, 1888, pp. 229-233) does not contain a single citation. As a correlative of the transportation of load by stream, its deposition was also considered, and a good beginning made toward recognizing the great importance of fluvial deposits in the case of an extensive conglomerate (Uinta, 170). In connection with the transportation of large boulders from mountains by storm floods, a curious suggestion is made (*Colorado River*, 208) regarding a possible similar interpretation of parts of the "Drift" in the upper Mississippi Valley, which Powell had studied while he was a professor in Illinois.

BASELEVEL OF EROSION.

Among all Powell's many generalizations none has been more broadly applied than his conception of the base level (now better printed as a single word, *baselevel*) of erosion. He wrote: "We may consider the level of the sea to be a grand base level, below which the dry lands cannot be eroded; but we may also have, for local or temporary purposes, other base levels of erosion, which are the levels of the beds of the principal streams which carry away the products of erosion. . . . What I have called the base level would, in fact, be an imaginary surface, inclining slightly in all its parts toward the lower end of the principal stream draining the area through which the level is supposed to extend, or having the inclination of its parts varied in direction as determined by tributary streams." Where a "stream crosses a series of rocks in its course, some of which are hard and others soft, the harder rocks form a series of temporary dams; . . . and thus we may have a series of base levels of erosion" (*Colorado River*, 203).

It is to be noted that *baselevel* as thus defined seems to have two meanings. One meaning is very simple; it is simply the level of the sea, extending in imagination under the lands. The other is much more complicated; it is an imaginary, undulating, and inclined surface passing through a river and its tributaries, but passing beneath the intervening land surfaces. And as thus defined *baselevel* must be conceived with difficulty because of the vagueness as to the stage of river devel-

opment when it is first to be applied, because of the irregularity of its form, and because of its slow changes as the controlling stream lines are worn down to gentler slopes. Naturally enough, the more complicated meaning has been little used. The simpler meaning now prevails, under which base-level may be concisely defined as the "level base" with respect to which river erosion is performed, determined either by sea-level in the most general case or by a rock-sill or lake surface or basin floor in various special cases. The idea thus presented is discoverable, provided the reader is already acquainted with it, as an implied factor of various explicit statements in the writings of certain earlier authors; but Powell makes it wholly explicit, and indeed sets it forth in a very striking and appealing manner. Moreover, he gave its leading element a handy name, as he did in the case of antecedent rivers, with the result of rapidly promoting a clear and general understanding of a principle of prime importance in the rational study of land forms. Simple as the principle here involved really is, the explicit announcement marks an era in rational physiography.

A second step of great importance followed from the first, as already intimated. The massive structures on which erosional processes operate having been conceived, the erosional processes themselves having been analyzed, and the baselevel with respect to which they work having been recognized, the successive steps in the progress of their work naturally became the subject of study. Powell clearly saw that mountain forms are not the result of disorderly and individual uplift, but of erosion. "The mountains were not thrust up as peaks, but a great block was slowly lifted, and from this the mountains were carved by the clouds—patient artists, who take what time may be necessary for their work. We speak of mountains forming clouds about their tops; the clouds have formed the mountains" (Colorado River, 154). This had been recognized by others, but Powell went further. "The first work of rains and rivers is to cut channels and divide the country into hills, and perhaps mountains, by many meandering grooves or watercourses, and when these have reached their local base levels, under the existing conditions, the hills are washed down, but not entirely carried away" (Colorado River, 204)—that is, a lowland of

small relief will in time be produced by the erosion of rain and rivers. Previous to Powell no one had ventured in the theory of land carving by rain and rivers to go beyond what would today be called a late-mature stage in the cycle of erosion—namely, the production of valleys between hills or mountains—unless one goes back to the brief generalization of the German philosopher, Kant, who a century earlier had recognized that the action of rain and streams must slowly wear down all highlands and rob the earth's surface of its inequalities; or to the broad principle of the Scotch geologist, Playfair, who a little later explained that the earth must tend gradually to become a spheroid of rotation by the external action of erosional forces, whatever its original form had been. But Powell is much more thoroughgoing and definite than any of his predecessors. He states in his second report, after recognizing the rapid wearing down of highlands: "The degradation of the last few inches of a broad area of land above the level of the sea would require a longer time than all the thousands of feet which might have been above it, so far as this degradation depends on mechanical processes; . . . but here the disintegration by solution and the transportation of the material by the agency of fluidity come in to assist the slow processes of mechanical degradation, and finally perform the chief part of the task" (Uinta, 196). This passage is of special interest as being the most explicit statement made by Powell regarding the general possibility that normal erosional processes, working on a land-mass long undisturbed, will ultimately reduce the whole surface to a lowland but little above sealevel. His full understanding of the problem is shown when he thus points out the contrast between what would now be called the rapid changes of the youthful stage early in a cycle of erosion and the extreme deliberation of advanced old age at the end of the cycle.

PLANATION.

These general results were not left without practical application. The great plains of erosion revealed by the superb unconformities in the bottom of the Grand Canyon of the Colorado in northern Arizona were evidently regarded as the

result of persistent erosion by rain and rivers during prolonged still-stands of the region in ancient geological periods; but the phraseology adopted for the peroration, in which the history of these buried lands is set forth, must leave the uninformed reader in some doubt as to the precise nature of the facts and inferences there presented. A simpler statement is given for the plateau-like highlands of crystalline schists, flanked by upturned sedimentaries in the Colorado Front Range, which had made a "deep impression" on Powell when he crossed them in his first Western journey in 1867. He afterward recalls that he had then "dimly conjectured that tens of thousands of feet had been eroded from some of the ranges, and that the table or plateau like character of the ranges was due to some epoch of this later denudation of the ranges when they were planed down to a common level. . . . Such a planing down occurs when the channels of the eroding streams remain for a great length of time at a general base level" (Uinta, 27). It would thus appear that the first observer to recognize this fundamental process in the origin of the Front Range of the Rocky Mountains was not Marvine, to whom it has elsewhere been credited, but Powell. True, he does not explicitly state that the planed-down surface of the Front Range was afterward broadly uplifted to its present highland altitude in order to excite its streams to erode the gorges by which it is now dissected; but no one who reads his reports can doubt that he understood the uplift as clearly as the planing down. Following the principles so well and so early applied in Colorado, he afterward perceived that the ranges of the Great Basin, though composed of Eozoic and Paleozoic rocks, are mountains of very late upheaval, and that before upheaval their region was "a comparatively low plain, constituting a general base level of erosion to which that region had been denuded in Mesozoic and early Tertiary time when it was an area of dry land" (Uinta, 32). He was thus led to say: "Mountains cannot long remain as mountains; they are ephemeral topographic forms. Geologically all existing mountains are recent; the ancient mountains are gone" (Uinta, 196). I can well recall the exclamatory vigor that Powell gave to a statement at a scientific meeting in 1884, and the emphasis that he added with

rapid gestures of his empty sleeve: "If the Adirondacks had been uplifted in Cambrian time"—as was then generally supposed—"they would have been worn down *over and over AGAIN!*"

The discussion of cliffs of displacement and cliffs of erosion in the Colorado River report is an excellent example of Powell's deductive presentation, evidently based upon observed examples, but systematically extended beyond their reach and admirably illustrated by a series of block diagrams by Holmes. The ideal types thus presented are shown in far greater distinctness than could be reached in any direct view of actual examples. It is well said that "the cliffs of erosion are very irregular in direction, but somewhat constant in vertical outline; and the cliffs of displacement are somewhat regular in direction, but very inconstant in vertical outline" (Colorado River, 191). This sentence may indeed be taken as one of the best examples of Powell's power in condensed verbal exposition. The migration of divides and the associated beheading of consequent streams during the retreat of cliffs of erosion is recognized (*Ibid.*, 210), but the principle here involved was not developed to its more general application.

PHYSIOGRAPHIC ESSAYS.

It is in the pages on the land forms of the Plateau province that one finds some of Powell's best physiographic presentation, much better than in two later essays on "Physiographic Processes" and "Physiographic Features," which he contributed to the series of "National Geographic Monographs" in 1895. These monographs were intended for school teachers of physical geography, who were then, as they are still, in too large a proportion very imperfectly trained in their science, and who therefore needed, as they still need, only elementary essays presenting specific examples in simple language. Whatever Powell's earlier experience in teaching school may have contributed to his style of presentation, his later experience as leader of exploring expeditions and as organizer and director of large scientific bureaus did not adapt it to the needs of the readers here appealed to. The simple style in which cliffs and canyons are described in the Colorado River report is re-

placed in these two essays by an elaborate, sometimes an extravagant, manner of statement little suited to school teachers. They are literal readers, and must have been mystified by such sentences as: "The purple cloud is painted with dust, and the sapphire sky is adamant on wings;" or, "With the revolving moon the tides sweep back and forth across the surface of the sea, and alternately lash the shores with their crested waves;" and it was certainly disappointing to those who had labored to introduce the principles of uniformitarian geology into geography to find the authority of Powell back of a statement telling "how fire, earthquake, and flood have been involved in fashioning the land and sea." The small attention given to marine processes in Powell's official reports, written in the environment of a broad continental interior, was natural enough; but the scanty systematic treatment that these processes received in comparison with the attention given to rain and rivers in the essay on "Physiographic Processes" was as little appropriate as the insufficient discussion of river work and the exaggerated consideration of marine processes by certain earlier transatlantic writers of a more insular environment.

The third essay of this series, on the "Physiographic Regions of the United States," is better than the other two. The subdivisions of our country into provinces, as there presented, has been often used by later writers, and must in its larger features be permanently adopted, because it is based on underground structure as the prime element in physiographic classification, rather than on an empirical examination of surface features, independent of their origin, such as had been accepted in earlier years when geographers and geologists hardly had a speaking acquaintance with one another. The correlation of structure and form in the Plateau region had been admirably set forth in the Uinta report by means of a block diagram (facing p. 14), which marked an immense advance over the black-bodied profiles then in common use, and even today unhappily not extinct. The same report had clearly separated the Basin Ranges, the Plateaus, and the Rocky Mountains: "first, desert valleys between naked ridges; second, high plateaus severed by profound gorges, and, third, massive high mountains with shining snow-fields" (Uinta, 8). This is sup-

plemented in the "Physiographic Regions" by the statement that the Rocky Mountains terminate in northern New Mexico, where the Basin Ranges stretch far southeastward to meet the southwestern border of the Great Plains. Subordinate changes in Powell's boundaries and subdivisions may of course be made, as in the interpolation of the group of domed mountains in western North Carolina between the Piedmont plateau and the Appalachian ridges, or in the separation of the highlands of northern Minnesota and upper Michigan from the Lake plains farther southeast; but in the main the demarcation of the provinces here indicated in text and map constitutes a permanent advance in American physiography. How singular that a practiced observer, keen enough to see that the Rocky Mountains end southward in New Mexico, should not have, as a writer for teachers, moderated the hyperbolic peroration which in the last lines of this essay described the California coast ranges as a province "where the balm of the tropics bathes the winter with verdure, and boreal zones boon the summer with zephyrs!"

It was in connection with the explanatory or rational description of land forms in terms of their past history as dependent on underground rock-structure and external erosive processes, that Powell ingeniously applied his analytical method in a reversed direction, as if confident that a good rule must work both ways, for he frequently inferred the past history of a district from its present form. The reading of past history from depositional records had long been a standard method in geology; reading past history from erosional records was a novelty. This is well illustrated in his conclusion that while each Basin Range "is but a small residuary fragment of the great inclined block" from which it has been carved, yet when compared to the Kaibab or the Uinta "the erosion of the Basin Range ridges sinks into insignificance;" hence "we are forced to conclusion that the conditions for great erosion now found in the Basin Ranges have existed but for a short period" (Uinta, 33, 34). This principle has had wide application in later years.

LANDS OF THE ARID REGION.

Powell's large share in promoting a correct knowledge of the arid parts of the United States and their possible utilization will not be realized by readers today unless they recall the time when so much was said about taking the words "Great American Desert" off of the map. This name was, during a period of early exploration, recklessly extended over vast areas of the West which are by no means completely desert; but as the frontier was pushed westward half a century ago, the restriction of the name was hardly less reckless than its extension. The existence of a desert was actually denied, although there certainly is a large space in the West and Southwest truly not altogether devoid of vegetation, but permanently "desert" in the economic sense, whatever its name. It was, of course, open to occupation in a limited manner, as nearly all deserts are; settlers who advanced into the dry country soon recognized that certain small areas in nearly every part of it could be redeemed by irrigation, and that much larger areas were not so barren but that wandering herds of cattle could subsist on their scanty herbage, provided that water was not too distant. Thus the region began to have a better reputation than it deserved; and, curiously enough, about coincident with a wave of rapid immigration into the pasturage area of the Great Plains in the '70's and '80's, there was a period of increasing rainfall in that subhumid region which was taken by many—even by army officers, who ought to have known better—to result from plowing the soil, laying rails, or stretching telegraph wires, and therefore regarded as a permanent improvement of climate. Farming was for a time successful, and this was enormously advertised. Thousands of settlers, accustomed to farming on the moist prairies of the Mississippi Valley, attempted in good faith to establish themselves on the drier Plains, only to be driven away with bitter disappointment and heavy loss when a few years later a period of less rainfall caused the failure of their crops.

The irrigated areas naturally had better fortune, especially the larger undertaking of the Mormons in Utah and of the Greeley district in Colorado. These advantageously located

areas are permanent assets of immense value to the West, and much profit now comes from many similar but smaller areas; but even the greenest spots in the most barren wilderness were always called settlements, and never oases. In various parts of the arid region the latter name would have been quite as appropriate as it is in the Sahara, but its connotation of a surrounding desert was too manifest to make it acceptable.

Powell told the truth about the dry country, and advocated a comprehensive plan whereby its real values might be developed. It was at his suggestion that Congress appointed a commission to study the physical and economic conditions of the arid region, and he gave two years to this work. We have no narrative of his Western journeys in this connection, but the results were published in a most important "Report on the Lands of the Arid Regions of the United States" in 1879, to which Gilbert, Dutton, and Thompson contributed chapters. Few reports have had a greater value in pointing out the direction of safe and sound progress. The first edition of 1,800 copies was soon exhausted, and a second edition of 5,000 was issued. The area treated was about four-tenths of that of the United States, and the report was the first comprehensive study of the kind issued in this country; today it is recognized as a classic treatise on the subject.

Powell cautiously set the limit of successful agriculture without irrigation—the singular art of dry farming was then unknown—at the line of 20 inches of average annual rainfall, and showed the danger that farming must run from frequent droughts east of this line in that belt of the Great Plains trending north and south, which lies between the rainfall lines of 20 and 28 inches and which he first called "subarid;" but the name "subarid" was later, on suggestions received in Washington, changed to "subhumid" as a less unpleasant term. He recognized an increasing stream supply during a decade previous to the preparation of his report; but, instead of explaining it, as many have done, by an increase of rainfall, he ascribed it to an increased "run-off" due to artificial changes in the land surface. It may be noted, in passing, that the term "run-off," now in general use, was invented by Powell; his correlated term "fly-off," for rainfall that is lost by evapora-

tion, has not been adopted. He scouted the idea that any operations of man can have brought about increased precipitation, but added, "if it be true that increase of the water supply is due to increase in precipitation, as many have supposed, the fact is not cheering to the agriculturist of the arid region. . . . Usually such changes go in cycles, and the opposite or compensating change may reasonably be anticipated," for if the increase of streams results from an increase of rainfall, "we shall have to expect a speedy return to extreme aridity, in which case a large portion of the agricultural industries of the country now growing up would be destroyed" (91). Powell plainly stated that only a small fraction of the arid lands was available for agriculture, and pointed out that the redemption of the areas that could be irrigated would involve difficult engineering problems far too large for individual farmers, and possible only through co-operative labor controlled by carefully considered legislation; he saw, further, that when all this should be accomplished only a small portion of the arid region could be cultivated. These principles are well enough understood now, after a generation of experience; but they were novelties when published, and served as needed corrections of exaggerated stories then current.

The report on the arid region proposed a fivefold classification of the Western public lands, not based on the traditions of the East, but on the facts and conditions of the West. The five classes were named mineral, coal, irrigable, pasturage, and timber lands. With mineral lands the report had nothing to do. The abundance and importance of lignite coals was briefly stated; they were, indeed, regarded as "inexhaustible by any population which the country can support for any length of time that human prevision can contemplate;" it was recommended that their area should be determined by a thorough geological survey. The areas classified as timber lands were chiefly the higher plateaus and mountains, which have practically no value aside from their forests; but it was explicitly stated that these areas were by no means wholly occupied by standing timber, because of the terrible devastation by forest fires. Emphatic warning was given of this danger in the arid region. Most of the fires were ascribed to intentional burning

by Indians, who, displaced from lower lands by the advance of white settlers and impelled to hunt fur-bearing animals for trade, deliberately set fire to the forests for the purpose of driving the game; therefore the Indians should be removed from the forested areas. The burning of forests in the highlands of the arid region has been on a "scale so vast that the amount taken from the lands for industrial purposes sinks by comparison into insignificance" (15). Powell tells that he had "witnessed two fires in Colorado, each of which destroyed more timber than all that used by the citizens of that State from its settlement to the present day, and at least three in Utah, each of which has destroyed more timber than that taken by the people of the Territory since its occupation. . . . Everywhere throughout the Rocky Mountain region the explorer, away from the beaten paths of civilization, meets great areas of dead forests; . . . in seasons of great drought the mountaineer sees the heavens filled with clouds of smoke. . . . If the fires are prevented, the renewal by annual growth will more than replace that taken by man. . . . No limitation to the use of the forests need be made" (17). "Once protected from fires, the forests will increase in extent and value. This protection, though sure to come at last, will be tardy" (18). It is interesting to note in this connection Powell's unqualified statement that "fire is the immediate cause of the lack of timber on the prairies" (16), and the emphasis that he gave to the occurrence of large burned areas in the East at the time of the discovery of America. He wrote several years later: "When the lands [in the East] were plowed the fires were stopped, and vast regions that were prairies at that time are now forest-clad. Today [1895] the forests of the United States are somewhat more extensive than they were at the landing of Columbus" (Nat. Geogr. Monogr., 71).

In classifying all the lands between the highland timber areas and the lowland irrigable areas as pasturage lands, Powell did not overlook that certain districts are really deserts, too low for timber, out of reach of irrigation, and too dry for pasture. He wrote: "In very low altitudes and latitudes the grasses are so scant as to be of no value; here the true deserts are found. These conditions obtain in southern California,

southern Nevada, southern Arizona, and southern New Mexico, where broad stretches of land are naked of vegetation; but in ascending to the higher lands the grass steadily increases" (20). The threefold classification therefore seems to have been for the sake of simplicity; surely the confident assertion of value in the larger part of the arid region as a cattle-raising country has been abundantly verified. The sparse growth of herbage on the grazing lands demanded large farm units; Powell advised that the minimum be set at four square miles, or 2,560 acres. He further advocated a somewhat ideal plan of settlement, in which the ranchmen's homes should be grouped around irrigable tracts, so as to secure the benefits of social organization, and, as he thought that fences would not be used, he inferred that the herds must roam freely under local communal regulations. Practice has not always verified these anticipations; roaming heads have been common on open public lands; but large areas of private lands are now enclosed by long fences of barbed wire, hardly known in 1879.

Work for a generation was laid out in Powell's far-sighted treatment of the irrigable districts. He showed that their total area must be small in relation to the vast extent of the whole arid region; he studied the amount of water that an irrigated farm would need, and concluded that a continuous flow of one cubic foot of water per second would serve from 80 to 100 acres; he advised a better construction of canals to prevent the excessive waste that was then almost universal. Streams must be gauged to determine how much land they can serve; reservoir sites must be reserved against the time when they will be needed to save the winter run-off. But the most significant sentences in this part of his remarkable report concern the danger of monopoly in the ownership of water, and in this respect Powell showed himself a pioneer conservationist. He doubted the wisdom of too rapid enterprise, prompted by the intense desire for speedy development on the part of first-comers, who give little heed to "philosophic considerations of political economy or to the ultimate condition of affairs in which their present enterprises will result. . . . If, in the eagerness for present development, a land-and-water system shall grow up in which the practical control of agriculture

shall fall into the hands of water companies, evils will result therefrom that generations may not be able to correct, and the very men who are now lauded as benefactors to the country will, in the ungovernable reaction which is sure to come, be denounced as oppressors of the people. *The right to use water should inhere in the land to be irrigated, and water rights should go with land titles*" (41). "The ancient principles of common law applying to the use of natural streams, so wise and equitable in a humid region, would, if applied to the arid region, practically prohibit the growth of its most important industries," because the water there "has no value in its natural channel. . . . Water rights are being practically severed from the natural channels of the streams; and this must be done. . . . In the change it is to be feared that water rights will in many cases be separated from all land rights as the system is now forming. If this fear is not groundless to the extent that such a separation is secured, water will become a property independent of the land, and this property will be gradually absorbed by a few. Monopolies of water will be secured, and the whole agriculture of the [arid] country will be tributary thereto—a condition of affairs which an American citizen having in view the interests of the largest number of people cannot contemplate with favor. . . . The right to the water should inhere in the land where it is used, . . . not to the individual or company constructing the canals by which it is used" (42, 43). A natural result of this invaluable report was Powell's appointment as a member of the Public Land Commission by the Senate and House of Representatives in 1879.

The enormous import of Powell's conclusions may be understood when it is recognized how many of them have been given practical application on a large scale, in more or less modified form, by governmental bureaus. Land classification and stream measurement are now important functions of our national Geological Survey; the same survey for a time reported upon reservoir sites and upon the area and value of forests, but the latter duty has later been given to the Forestry Bureau, under which the greatest efforts are made to secure adequate protection from forest fires; the difficulty which

makes this protection "tardy," as Powell predicted it would be, not being found in mere problems of administration, but altogether in the failure of a negligent Congress to provide adequate funds for the relatively moderate expense involved. The survey of reservoir sites and the large engineering works, foreseen as necessary for the full development of the possibilities of irrigation, are now conducted on an enormous scale by the Reclamation Service, an outgrowth of a branch of the Geological Survey and one of the best and most beneficent of our governmental undertakings. The introduction of electric-power plants, advantageously installed in connection with irrigation dams, and of immense economic value in using a natural supply of energy that would otherwise be wasted, have only increased the importance of everything that Powell said regarding the necessity of guarding our water supplies from monopolistic control and conserving them for the common good.

When all this is appreciated, Powell must come to be regarded as one of our great national benefactors. The opinions of two highly competent judges may here be quoted. Gilbert wrote, in effect, that Powell's Report on the Lands of the Arid Regions set forth with marvelous insight the conditions by which the problem of their best utilization is surrounded; his views were discredited at the time, because he announced that only a small percentage of the Far West can ever be reclaimed for agriculture. The Report raised a storm of indignation, because it characterized as semi-arid the middle belt of the Plains, toward which settlement was then tending, yet today it is recognized as a classic treatise.

Van Hise wrote in a similar vein, telling how Powell gave the benefit of his knowledge of the arid regions to the legislators of the nation. He saw that the arid lands were a possible great resource to the country, but an exceptional resource, which could not be wisely handled under the common law as it had been developed in humid regions. He saw that there was no danger of monopoly of land, but that the real danger was the monopoly of water—that he who controlled the water was the master of the land. Consequently he proposed broad and statesmanlike legislation for the division of the lands of the

West which are not mining lands into several classes, and advised that these lands should be controlled by special laws.

The suggestions which Powell made regarding the economic problems here treated have been in large measure incorporated into statutes. The effort for reform was complicated by conflicting interests, and at times it was a disheartening struggle; but it is a pleasure to record that during the Major's last sickness he was able to know of the passage of the Reclamation Act, the most important triumph of the arid-lands agitation.

THE GEOLOGICAL SURVEY.

In no case was Powell's capacity to turn the course of events more strikingly shown than in the organization of our present national Geological Survey. Through the '70's the existence of several official yet independent surveys of the Western country under different departments of the Government resulted in scandalous rivalries and animosities. Powell, at the head of one of these organizations, strove to reach an adjustment by mutual consent; failing in this, he boldly advocated complete reorganization. He had advised the consolidation of the several rival surveys in 1874, and it appears to have been at his suggestion that Congress, in June, 1878, called upon the National Academy of Sciences, of which he was then not a member, for advice. A committee of the Academy reported in November a plan which had been, in its main features, formulated and advocated by Powell, involving the abolition of the rival surveys and the creation of two separate bureaus—one, an enlargement of the Coast Survey under the title of Coast and Interior Survey, for geodetic and topographic mensuration; the other, a Geological Survey for studies of structure and resources, not of the United States, but of the "public domain;" all matters concerning the disposition and sale of public lands being left to the General Land Office. The present generation should be reminded that, during the discussion of the recommended organization, strong pressure was brought to bear upon Congress in favor of placing all topographic surveys in charge of the Engineer Corps of the Army, and European precedents for this plan were

abundantly cited. But it was urged, on the other hand, that our needs would be better served by civil rather than by military engineers, because the uses of our public domain would be much more largely in the way of peaceful settlement than of warlike campaigns. On this point, as on many others, Powell's opinion seems to have had weight. His view of the entire problem was presented in a letter as a supplement to the report of the Committee of the National Academy; and this letter the Hon. Abram S. Hewitt, then a leading member of the House of Representatives, urged all his colleagues to read, because the whole subject of reorganization of the surveys was there "so much better treated than any gentleman on the floor can hope to do."

The "Geological Survey" was established by an act of Congress on March 3, 1879. Although its work was, as noted above, limited to the "public domain," the name "United States Geological Survey" was at once assumed. A Bureau of Ethnology was created at about the same time, but the duties of the Coast Survey and the Land Office were not changed, and no special provision was made for a topographic survey. It is significant that the law establishing the Geological Survey mentioned the classification of the public lands before the examination of their geological structure. It is significant also that on account of Powell's active share in bringing the new Survey into existence he refused to be considered a candidate for its directorship. He was appointed instead to the directorship of the Bureau of Ethnology, and Clarence King, previously chief of the famous Fortieth Parallel Survey, was appointed Director of the new Geological Survey in March, 1879; he resigned two years later on the ground of preferring personal investigation to administration. Powell, believing his duty in the Bureau of Ethnology to be permanent and engrossing, had given up "all thought of continuing his work as a geologist;" but he was appointed Director of the Geological Survey after King's resignation, while still retaining his other directorship, and returned to geological work in March, 1881, with vigor and enthusiasm.

Many of the activities of the Geological Survey were then for over ten years so characteristic of Powell's method of work

that an account of them deserves an important place in a memoir of his life. The breadth of the organization reflected his native interest in comprehensive schemes and his unusual capacity in developing them. King had already secured the services of a number of geologists from the several surveys that had been disbanded and Powell brought in still others; thus a good volume of inherited work was quickly brought forward for publication. He had in Gilbert a wise adviser on scientific problems and in McChesney an able aid in all financial matters. The enlistment of many professors of geology in colleges all over the country, to contribute reports on subjects that they had previously studied independently, showed the broadly inclusive spirit in which the development of the Survey was conceived; thus the Director secured the personal interest of many widely distributed experts in the maintenance of the Survey, and at the same time brought together much accumulated knowledge in local or special fields. This was a wise step at the beginning, when the supply of well-trained young American geologists was small; but such a method of securing field geologists was outgrown half a generation later, when the students of the professors of the earlier time had in good number become expert members of the Survey, practiced in methods adapted to its special needs, and not distracted from its work by duties to other institutions. The standard of technical preparation expected of members in various branches of geology and topography was at the outset necessarily low, for there had been no demand to excite a well-trained supply, and the pressure of Congressmen to secure places for their relatives and friends did not tend to raise the standard; but it was raised as rapidly as possible, and the Survey thus reacted most helpfully on the development of the geological departments in our universities. In the meantime, if "Senators' nephews" sometimes gained positions as camp assistants or rodmen, they were seldom capable of geological work, and in any case Powell squarely accepted all responsibility as to the character of his appointees. He wrote in the Sixth Annual Report: "If, then, improper persons are employed, it is wholly the Director's fault."

A liberal policy was adopted regarding the exchange of the

Survey publications with productive geologists, whereby many an isolated worker was kept in touch with the progress of the great national undertaking. The early reports and monographs were, moreover, of exceptional interest and immediately commanded the admiration of the whole geological world. A sound method of business administration was developed. Powell's detailed account of it before a Joint Commission of Congress in 1885 made a most favorable impression on the majority of the Senators and Representatives who heard him. A full statement of this matter is given in systematic form in the Eighth Annual Report, and a brief statement of the organization of the Survey was communicated to the National Academy in 1884 and printed in the *American Journal of Science* for February, 1885; but it is the original report of the Joint Commission, an exceptionally interesting public document, published in the form of questions and answers usual in such cases, that best shows Powell's close familiarity with all details of survey work and his remarkable competence in setting forth methods of administration. Those who were then members of the Survey will remember how nearly every one was for a time pressed into the work of summarizing the reports of foreign topographical and geological surveys, so that the Director should have precise and detailed information in his hands; his testimony illustrates how ably he used the varied material thus placed at his disposal.

Powell's third report—the Fourth Annual Report of the Survey—announces that the congressional act making appropriations for the Survey for 1882-1883 required the preparation of "a geologic map of the United States;" thus for the first time explicit authority was given for extending the operations of the Survey over the whole country, and therewith implicit authority for the preparation of a topographic map as the necessary basis of the geologic map. Who can say how far Powell himself suggested the use of these highly significant words! Reports on topographic work were thereafter placed at the head of the list of administrative statements in the annual reports issued by Powell. The failure of Congress to establish three years before an independent topographic bureau was thus repaired, and by a curious combination of cir-

cumstances Powell found himself in charge of both classes of work—topographic and geologic—that had been assigned to separate bureaus in the recommendation of the National Academy, and of the work in the Bureau of Ethnology as well. About six years later, 1888, the conduct of an Irrigation Survey was also placed under his charge; never before or since has so large and so varied a scientific responsibility been concentrated in the hands of a single governmental official at Washington.

TOPOGRAPHICAL MAP.

The sheets of the topographical map surveyed, drawn, and printed by the Survey have been immensely serviceable; indeed, no publications of the Survey have had up to the present date a greater general usefulness than this map, which, under Powell's strong initiative, was undertaken for the whole country. Scientists of the younger generation, who are now profiting from the large supply of good maps available for their uses, can hardly appreciate the rarity of cartographic material regarding nearly every part of our country—the coasts and the lake shores excepted—thirty years ago. The change from geographic barbarism of that earlier day to the relative civilization of the present time is due more to Powell than to any other one man, and in accomplishing this change Gannett was for many years his right hand.

The plan for the topographic survey of the United States is set forth in the Sixth and Seventh Annual Reports. "The map should be so simple that it can be used by all people of intelligence. . . . The uses for topographic maps . . . are very many; but there is no demand more exacting than that made by the geologist, and if properly made to meet his wants they will subserve the purposes of the civil engineer and the agriculturist, the military engineer and the naturalist." Map-making in Europe had been largely in the hands of military engineers, as has been intimated above, and maps had been there prepared chiefly for military or cadastral purposes. Our needs are neither military nor cadastral, but civil and general, and our methods must meet our needs. "No nation had yet undertaken to execute a work of this character over a region of such magnitude. It has therefore been deemed of

prime importance that the survey should be conducted with utmost regard to economy." Relief had usually been represented by shading or by hachures; shading is too vague, hachures are too expensive, contours are definite and not over costly; hence contour maps were determined upon. Co-operative work with States, first undertaken in 1884 with Massachusetts, has since then been greatly extended. Singularly enough, no provision was made at first for the sale of the topographic sheets to the public; but when this was allowed the price did not include any part of the cost of production apart from paper and printing; a wide distribution was thus secured. The same wise method was early applied in determining the price asked for Survey reports and later for geologic folios.

The plans as outlined at the beginning of this great topographic work were admirable; the difficulty of executing them was great. Liberal sums were available for topographic surveying, but for a time it was impossible to find trained topographers in the desired number; hence many insufficiently trained men had to be employed and their training came in the field. The pressure for the rapid production of maps at moderate cost over large areas led to hasty work insufficiently inspected; hence the published maps were not always correct to scale of publication. In some cases the dangerous practice was permitted of redrawing in new form the maps produced by previous surveys, and as a result certain sheets of deplorable inaccuracy were issued; some of these exhibit features that are hardly recognizable on the excellent maps of later date for the same districts. Nevertheless, progress toward greater accuracy was rapid afterward, when better methods were introduced and greater cost was allowed per square mile; and it may now be seriously questioned whether the large number of excellent maps annually issued at present could have been so soon reached in any way but by plunging in boldly and rapidly instead of slowly and accurately at the beginning. Certain it is that the revelation of geographical matters of fact regarding large areas of our country, as portrayed on the sheets issued during the last ten or fifteen years, is of immense service to us all today; and this service must be counted as a consequence of Powell's marvelous initiative.

REPORTS AND FOLIOS.

The many geological studies published in annual reports, monographs, bulletins, and folios exhibit admirably the work of individual members of the Survey; but they reflect credit also on the Director, who knew how to select good associates, and who wisely trusted them with great responsibilities and gave them great liberty of action. Powell, indeed, had so much native capacity that he never hesitated, as a weaker Director might have done, to employ men who knew more geology than he did himself. The "Correlation Papers," prepared according to a general plan by eleven specialists under Gilbert's supervision to summarize knowledge regarding successive geological periods, contributed greatly to a broad understanding of large problems; and these papers constitute a thoroughly characteristic product of Powell's administration. The annual volumes giving statistical summaries of mineral resources also deserve special mention as initiated under Powell's direction. They are probably as accurate as possible under the conditions of their preparation, but they are probably not so accurate as they appear to be. The geologic folios, containing sheets of the geological map of the United States which the Survey had been instructed to prepare, are based on a uniform and comprehensive plan, and exhibit, like the topographic maps, Powell's remarkable foresight and breadth of view. The plan for the publication of the folios was carefully discussed in several conferences of leading geologists; careful debate was given to the general explanatory text of the cover, to the scheme of coloring, so admirably carried into effect by the engraving department of the Survey, and to the liberal presentation of topography, geology, structure, and economic features on separate sheets, all this being told in the Tenth Annual Report (1888-1889). The first geologic folio was issued in 1892, thirteen years after the establishment of the Survey; later folios show marked improvement in various directions, the text in particular becoming more elaborate and pictorial illustrations were abundant; but the original plan is still followed, except for the inevitable departure from the intention that the text should be "so prepared as to be intelli-

gible to users who are not trained geologists." This feature of the plan has not been carried out, and cannot be carried out unless a great part of the laborious and expensive accumulation of scientific fact and inference is not published in direct connection with the geological map to which it so closely applies. Certain critics have questioned whether another form of publication than a large folio would not be more generally useful, and some folios have lately been prepared in the form of bulletins with folded maps for field use; but for purposes of study in every other place than on the ground the folio form introduced under Powell is the most convenient. If the whole series of folios, when completed, proves to be a heavy care for any library, this must be charged against the glorious misfortune of our large national area.

IRRIGATION SURVEY.

The Tenth Annual Report tells of the Irrigation Survey, instituted in 1888, as a department of the Geological Survey, for the determination of the extent to which arid districts can be redeemed by irrigation and for the selection of sites for reservoirs, but not the construction of irrigation works. This was a fitting though a delayed consequence of the report on the arid lands ten years earlier; but it added a heavy weight to the duties of the Director, and probably led to the appointment of Gilbert in 1889, and later of Walcott, as chief geologist. The establishment of the Irrigation Survey must be regarded as having been prompted by Powell himself, for he had continually urged upon Congress the necessity of making appropriations for such investigations, and had delivered addresses and written magazine articles on the same subject. Although the irrigation work was cut off in 1892, much progress in this direction was accomplished, as attested first by the growth for several years in the size of the special annual reports on irrigation problems and fourteen years later by the establishment of the Reclamation Service; and all this must be credited to Powell's initiative and to the enthusiasm that he aroused in the younger men whom he selected to carry on the work.

ADMINISTRATION.

The various aspects of the Geological Survey here summarized from successive volumes of Annual Reports reflect clearly enough the character impressed on this great organization by Powell as its Director; but they give a very imperfect picture of the labor demanded of him in maintaining the Survey. A governmental bureau depends on one side upon the annual appropriations of a changing Congress, and on the other side upon the loyal and expert work of its many members. The continuation of such a bureau and the fate of its members might be left by a philosophical outsider entirely to the wisdom of Congressmen, because in the abstract the bureau exists only to carry out the will of the people as expressed by their Representatives; but in the concrete case of any single bureau, especially of a bureau originally established for the performance of a great and long-enduring task, many other considerations enter into the problem, as Powell well knew, and weighty among these is a reasonable assurance of steady employment for those who have in good faith cast their lot in the work of the bureau, with a fair expectation of its long existence, and also an honorable ambition of the Director regarding the distant completion of the important task committed to his charge, already begun or planned for the immediate future. Not only general continuity of work, but steadiness in rate of work—or at least the avoidance of a decreasing rate—is essential for an employee's peace of mind and a Director's satisfaction; increase may be welcomed, but retrenchment is at once an embarrassment to the Director who is compelled to execute it, and a hardship to those upon whom it is executed. The approach of the critical season when Congressional appropriations are usually voted is, therefore, unavoidably a time of anxiety for the members of a bureau in which the work necessarily changes to some extent every year, for some members must lose their positions if the work is reduced; and it is a particularly anxious time to the Director, upon whom the responsibility for maintaining the bureau so largely depends; all the more so to a Director who, like "the

Major," felt a deep personal solicitude for the welfare of his fellow-workers, as if they were members of his family.

The internal organization of a scientific bureau is, as compared to this external responsibility, an enjoyable pastime to an able Director surrounded by loyal associates. One can, indeed, feel when looking over the annual administrative reports of the Geological Survey that Powell had a lively pleasure in the internal part of his work, and the same impression was given to visitors who, from time to time, heard him humming a tune as he made his way through the corridors of the Survey building to look at the work of some of his staff. If one may judge by the years of the rapidly ascending development of the Survey from 1881 to 1892, when Powell's staunch friends in Congress acted so heartily upon his suggestions and gave him practically every opportunity that he asked for, he had during that notable period as small a share of external anxiety as the head of a great bureau can expect; yet it must not be overlooked that during this famous decade of geological evolution no small amount of Powell's time was demanded in presenting his plans even to the more friendly members of Congressional committees, and no small measure of skill and patience was needed in winning the support of the less friendly members. But Powell was master here, as well as in a boat trip down the Colorado; he had enthusiasm for the work to be accomplished; he was deeply impressed with its great importance in the development of the country; he was honest in his presentation of its merits; moreover, he understood human nature pretty well, and knew how to deal with men of many kinds; and he had so full command of all pertinent facts that his opponents in Congressional committees were often left with nothing but their opposition to stand on. He doubtless deserved the reputation gained in the minds of persons long acquainted with Washington affairs, of being for the first ten years of his directorate eminently successful in accomplishing what he set out to accomplish, and in securing such Congressional enactments and appropriations as he wished to secure.

Naturally, therefore, the growth of the Geological Survey was phenomenal. It began with an appropriation of \$100,000

and with 39 members on its pay-roll for the year ending June 30, 1880; for 1881-1882, the first full year of Powell's directorate, the figures were \$156,000 and 50; in 1890-1891, the maximum appropriation of \$719,000 was reached; the next year there was a moderate decrease to \$631,000. This unrivalled development was accompanied by a swelling volume of publications of all kinds. It is not too much to say that the eyes of the geological world were turned in astonished admiration at so unprecedented an expansion, which had rapidly brought the United States Geological Survey under Powell's leadership to be not only the largest organization of its kind, but the largest scientific organization of any kind in the world. Instead of Philadelphia, as at first suggested, Washington became the inevitable place of meeting for the International Geological Congress of 1891; at the close of the Western excursion that followed the Congress, Powell led a party of visiting geologists across the Arizona plateau to the Colorado canyon, and seemed to enjoy giving the European members a sample of the rough conditions under which travel had then to be prosecuted in the Far West. The following winter the Cuvier prize was fittingly awarded "to the collective work of the Survey" by the Academy of Sciences of Paris.

RESIGNATION FROM THE SURVEY.

But even up to this time all had not been clear sailing in Washington. Already, in 1884, opposition to the rapid growth of the Survey, instigated, it is said, by some of those who were left out of the Government service in the reorganization of 1879, had arisen in Congress; the Joint Commission, above referred to, was its outcome. Powell's testimony disclosed, however, so perfect an organization, he showed himself so completely in control of it, and his "statement traversing certain averments" made by members of the opposing minority in Congress was so satisfying to his friends in the majority, that he came out victorious from the ordeal. The appropriation of nearly half a million for the Survey for the year ending June 30, 1885, was, in the face of the organized opposition, raised to a little over half a million for 1885-1886, and so con-

tinued for the next two years; it was raised to \$605,000 for 1888-1889, reduced to \$551,000 for 1889-1890, and reached the maximum of \$719,000 for 1890-1891.

The decrease of nearly \$90,000 for the following year marked the opening of a period of adversity which culminated in the summer of 1892. The establishment of the Irrigation Survey four years before had aroused the opposition of large land-owners and cattle kings in the West, a result that was not unexpected when the scientific administration of a public bureau in the interests of the country as a whole clashed with the personal interests of men who were rapidly growing rich under the unrestricted use of public resources; and unhappily, at about the same time, Powell's wounded arm gave him much pain; the suffering thus caused made it difficult for him to labor with Congressional committees as successfully as he had before. The first successful stroke of the opposition was made in 1891, not only by the reduction of the appropriation for the year ending June 30, 1892, as above noted, but further by the assignment of definite sums for the salaries of designated members of the Survey and for special branches of work; work on irrigation was not mentioned and was therefore suspended.

The following year was nothing less than disastrous. The appropriation for the year ending June 30, 1893, voted at the late date of August 5, 1892, fell to \$430,000; definite sums were assigned to work and salaries as before; but now fourteen stated salaries were discontinued, and at the same time the amount of money assigned to topographic surveys was so large a part of the total that the balance left for geology was scanty. Field work was in active progress by a number of divisions of the geological branch when this blow fell. It was stopped by telegraphic orders, and the workers were directed to prepare records already in hand for publication, or at least to put their material into systematic shape, so that it might be used later. Many salaries that were not cut off entirely were seriously reduced; some members of the Survey voluntarily worked through the following winter on small pay or no pay. It was a time of distress. The next year the appropriation was raised to nearly \$500,000; but the volume in which this is announced opens with a page from Powell to his collaborators,

taking leave of them; his resignation, to take effect June 30, 1894, had been announced some months before. The burden of his work had grown, and its difficulties had been aggravated by antagonism; his poor health did not allow him to suffer the irritation of conflicts; his withdrawal from the Survey was made "necessary by painful disability," and he devoted himself thenceforward to the simpler duties of the Bureau of Ethnology, of which he continued to be the chief.

Powell's administration of the Survey was extraordinary in many respects. He was a strong, independent, and aggressive leader, as was to be expected in view of his freely expressed indifference to traditions and conventionalities. He was truly a director by nature, and so confident of his power that he never hesitated to appoint able men as his subordinates. His authority was maintained without resort to the formalities of rank; indeed, he replaced with a jovial comradeship the lofty inaccessibility not unknown in some official bureaus, American as well as European. He had a keen sense of justice. I well remember the outburst of indignation with which he replied at a scientific meeting to a speaker who had referred unfairly to the work of an absent colleague. He felt a warm personal interest in the work of his associates; more than one junior has felt the cheer of his sympathetic appreciation. He attached the members of the Survey to its service and secured their devoted and loyal support because he was helpful, trustful, and encouraging to them—when he was convinced that he had good grounds for being so. He felt a personal solicitude for the future of the workers in the Survey that outlasted his directorship. Withdrawal from office under a sense of disappointment was a sad ending to the vast work of creation and organization that Powell had guided almost from its beginning; but he had at least in the decade that followed the satisfaction of seeing the return of the Survey to a period of growth and prosperity under the direction of his successor, who had long been associated with him and to whom at the end of a difficult piece of work ten years earlier he had said—the older man putting his one arm around the younger—"My boy, you have done well; I hope you will stay with us."

RESIDENCE IN WASHINGTON.

We may here introduce between the accounts of Powell's work in Geology and in Ethnology a brief statement of his personal relations with his associates and of his large share in organizing and supporting scientific societies in the National Capital. His Washington home at 910 M street N. W. was for many years recognized as a scientific center not only for employees under his charge, but for the scientific men of Washington in general. It was in his parlor that the Cosmos Club was organized in 1878; he was then made its temporary president and became formally the president of the permanent organization on January 10, 1881. The club has now more than 600 resident and 350 non-resident members, and includes therein most of the representatives of science, literature, and art in the National Capital. Through the winter of 1883 an informal reception was held in Major Powell's parlor every Sunday evening for the members of the Geological Survey and Bureau of Ethnology, but these receptions soon grew too large to permit of their continuation.

Powell's large share in developing non-official scientific interests in Washington may be inferred from his relation to the following societies, most of which have their seat in the National Capital. He held at one time or another membership in the Anthropological Society of Washington, of which he was a founder, and also President in 1879-1882, 1883-1885, 1887, and 1895; in the American Anthropological Association, of which he was a founder; in the Washington Academy of Sciences, of which he was an incorporator and vice-president; in the National Geographic Society, of which he was an incorporator; in the American Association for the Advancement of Science, of which he was president in 1888; in the National Academy of Sciences; in the Philosophical, the Biological, the Chemical, and the Geological Societies of Washington; in the Geological Society of America, of which he was one of the first councillors, and in the American Folk-lore Society. He was known to be an associate member of the Société d'Anthropologie of Paris, and a corresponding member of the Berliner Gesellschaft für Anthropologie, Ethnologie und Urgeschichte;

but whether this completes the list of his foreign membership it as been impossible to determine.

ETHNOLOGICAL WORK.

Although Powell is probably known to a greater number of persons as a geologist than as an ethnologist, his publications on ethnology and anthropology and on the philosophical problems into which the study of these sciences led him are—apart from purely administrative reports—twice as numerous as those on geology; and it appears that his contributions to the content of the sciences of earth and of man stand in about the same proportion. His active interest in ethnology began when he came into contact with the Indian tribes of western Colorado and eastern Utah in the summer of 1868; it was probably reinforced by Secretary Henry's advice that special study of the Indians should be made during the canyon journey of the next year. But more important than its origin is the nature of the interest that Powell felt in ethnology; for it had the merit of being characterized by a willingness to recognize other standards than those of the civilized races of mankind, by a ready capacity to appreciate the position of the "other fellow," and by a sincere respect for humanity in all its stages of development. These are largely matters of temperament, not of learning; they are of prime importance to an ethnologist in the office as well as in the field. Gilbert gave emphasis to this point when he wrote that Powell "realized, as perhaps few had realized before him, that the point of view of the savage is essentially different from that of the civilized man; that just as his music cannot be recorded in the notation of civilized music, just as his words cannot be written with the English alphabet, so the structure of his language transcends the formulæ of Aryan grammars, and his philosophy and social organization follow lines unknown to the European."

The warm-hearted sympathy that was the basis of Powell's success in the field study of Indian tribes is nowhere better illustrated than in the comment he makes on the fate of the three men who left his party and climbed out of the Colorado canyon in August, 1869, as already briefly narrated. The story

was learned a year later by Jacob Hamblin, a Mormon missionary among the Indians, who spoke their language well and had great influence among them, and who was with Powell's party in the summer of 1870 on the plateau north of the canyon, not far from the point where the three men had ascended from the river the year before. "They came upon the Indian village almost starved and exhausted with fatigue. They were supplied with food and put on their way to the settlements. Shortly after they had left, an Indian from the east side of the Colorado arrived at the village and told them about a number of miners having killed a squaw in a drunken brawl, and no doubt these were the men. No person had ever come down the canyon; that was impossible; they were trying to hide their guilt. . . . In this way he worked them into a great rage. They followed, surrounded the men in ambush and filled them full of arrows." Powell's comment on this pitiful story contains not a thought of revenge or even of punishment; he realized that primitive and advanced men do not think alike and he respected the Indians' idea of justice. "That night I slept in peace, although these murderers of my men, and their friends, the *U-in-ka-rets*, were sleeping not five hundred yards away. While we were gone to the cañon, the pack-train and supplies, enough to make an Indian rich beyond his wildest dreams, were all left in their charge and were all safe; not even a lump of sugar was pilfered by the children" (Colorado River, 130, 131). Some years later Powell explicitly stated his creed in this matter: "When I stand before the sacred fire in an Indian village and listen to the red man's philosophy, no anger stirs my blood. I love him as one of my kind" (Philosophical Bearings of Darwinism, Washington, 1882, p. 12).

Powell's interest in Indian customs and languages was at first combined with some attention to problems in the practical administration of Indian affairs; he was appointed by Congress in 1872 (?) a commissioner to examine the condition of certain tribes in the Far West, and his report, made jointly with G. W. Ingalls, was his first ethnological publication (1874). It was at this time that he discussed the "causes and remedies for the inevitable conflict that arises from the spread of civilization over a region previously inhabited by savages;" but in

his later studies the Indians, unmodified by contact with the whites, were his subject.

Secretary Henry, of the Smithsonian Institution, who had early given Powell encouragement and assistance in the direction of ethnology, was greatly impressed with the exploration of the Colorado, regarding the report upon which he later wrote: "The whole work will do honor to the appreciation by the Government of scientific information of this kind, as well as of the ability and perseverance of Professor Powell and his assistants." It was evidently on the basis of this good opinion that, after Powell had turned from geology to ethnology in the early '70's, much material collected by the Smithsonian Institution was placed in his hands: this included 670 Indian vocabularies which had previously been submitted to Trumbull, and it was upon this extended basis that Powell prepared his first "Introduction to the study of Indian languages" (1877), an enlarged edition of which was published three years later.

BUREAU OF ETHNOLOGY.

A natural consequence of all this was that, when the Bureau of Ethnology was organized by act of Congress in 1879, Powell was made its Director, a post which he held with great distinction for twenty-three years. He entered upon these duties with the expectation of devoting the rest of his life to them, for at that time he had given up all thought of continuing his geological studies; yet only two years later he was at the head of the Geological Survey, as has already been told. It is astonishing that he could, for a period of twelve years, so ably direct both these important organizations; it is natural enough that, after having resigned his place as Director of the Geological Survey in 1894, he should continue until the end of his life in charge of his other and less onerous duties. If the Bureau of Ethnology did not reach the ideal development that he had contemplated and hoped, it nevertheless gained a highly respected scientific position. It was administered at no great cost; the appropriations ran from \$20,000 at the outset to \$50,000 in the last year of Powell's administration; the appropriation bill sometimes contained the thrifty item that "not

exceeding one thousand dollars may be used for rent of building." The object of the Bureau, as defined in its reports, was the prosecution of research by the direct employment of scholars and specialists in the Bureau itself, and by the promotion of research by collaborators elsewhere through the country. As far as the general progress of ethnology was concerned, Powell's great service here, as in geology, lay in organizing a corps of experts, in providing opportunity for their steady work under good conditions, in directing their work wisely, and in securing assurance of fitting publication for their results. In the opinion of an experienced Washington official, Powell worked little less than a revolution in educating Congress to bring the trained scientific expert into Government research. Twenty-three large volumes of Annual Reports of the Bureau, issued under Powell's direction, mark an epoch in American ethnology. But besides organizing this important Bureau, Powell took a leading part in its work. He gave much thought for many years, as well as all the time that he could spare, to problems connected with the life and customs of the American Indian; his favorite subjects for essays and addresses were chosen from topics of the same nature and from the philosophical problems to which they led.

INDIAN LANGUAGES AND MYTHOLOGY.

Powell's attention was early turned to the speech of Indian tribes, because he felt that a knowledge of languages was fundamental in gaining an understanding of other and more important characteristics—namely, thoughts and acts as embodied in customs, institutions, and religions. An elaborate Bibliography of North American Philology was undertaken by his associate, Pilling, and Powell himself gave much time to the study of Indian tongues in the field and office; the monograph on Indian linguistic families, to which these studies led, is further considered below.

In the First Annual Report of the Bureau of Ethnology for 1879-1880 (1881) Powell's strong bent toward the treatment of problems in generalized form is indicated by his discussing so large a subject as the "Evolution of language" in an essay

that had previously served him as presidential address before the Anthropological Society of Washington in 1880. It treats the specialization of the grammatic processes, the differentiation of the parts of speech, and the integration of the sentence, and affords profitable reading for persons of classical training, because it opens up surprising possibilities in the way of linguistic structure to which the languages of Europe are strangers. "Many conditions and qualifications appear in the verb [of the Indian languages] which in English and other civilized languages appear as adverbs and adverbial phrases and clauses." Again, Indian verbs often express a larger meaning than we are accustomed to compress into a single word; thus "the English verb *to go* may be represented [in an Indian language] by a word signifying to go home; another, go away from home; another, go to a place other than home; . . . one, to go up; another, to go down; . . . another, go up a valley; another, go up a river." But "it is in the genders of the article pronouns that the greatest difficulty may be found. The student must entirely free his mind of the idea that gender is simply a distinction of sex. . . . Often by these genders all objects are classified by characteristics found in their attributes or supposed constitution. Thus we may have the animate and inanimate, one or both, divided into the standing, the sitting, and the lying; or they may be divided into the watery, the mushy, the earthy, the stony, the woody, and the fleshy."

The extracts quoted below indicate some of the chief conclusions reached, and at the same time point out Powell's practical view of linguistic evolution—a view as natural in a man of his surroundings and training as it would be unnatural in a graduate of Eton and Oxford. "It is worthy of remark," he writes, "that all paradigmatic inflection in a civilized tongue is a relic of its barbarous condition. When the parts of speech are fully differentiated and the process of placement fully specialized, so that the order of words in sentences has its full significance, no useful purpose is subserved by inflection" (p. 15). He insisted that inflection is not economical, because "the speaker is compelled, in the choice of a word to express his idea, to think of a multiplicity of things which have no con-

nection with that which he wishes to express" (16). Thus judged, "English stands alone in the highest rank; but as a written language, in the way in which its alphabet is used, the English has but emerged from a barbaric condition" (16). He later returns to the same topic: "Men with linguistic superstitions mourn the degeneracy of English, German, and French without being aware of the great improvement which has been made in them as instruments for the expression of thought" (20th Ann. Rept., 1898-1899, 1903, p. CLII). After reading these extracts it is hardly necessary to add that Powell was an advocate of the introduction of simplified spelling, for the distinction between its advocates and its opponents is almost wholly a matter of temperament, not of learning.

The First Annual Report of the Bureau also contains one of Powell's earliest philosophical essays, entitled "Sketch of the mythology of the North American Indians," which he had read as a vice-presidential address before a section of the American Association for the Advancement of Science in 1879, under the title of "Mythologic Philosophy." Its headings are: "The genesis of philosophy," "Two grand stages of philosophy," "Mythologic philosophy has four stages," and so on. From the second heading the following characteristic aphorism may be quoted: "The unknown known is the philosophy of savagery; the known unknown is the philosophy of civilization." And then comes an exclamatory apostrophe, as if in scorn of our self-sufficiency: "Ye men of science, ye wise fools, ye have discovered the law of gravity, but ye cannot tell what gravity is. But savagery has a cause and a method for all things; nothing is left unexplained" (pp. 21, 22, 29).

SAVAGERY, BARBARISM, AND CIVILIZATION.

Powell's capacity to frame concise summaries of elaborate studies is well illustrated in a "brief characterization of savagery, barbarism, and civilization," in which he summarizes the chief points of his addresses on "From Savagery to Barbarism" and "From Barbarism to Civilization," and out of which the following extracts are taken, with some rearrangement: "The age of savagery is the age of stone; the age of barbarism is the age of clay; the age of civilization is the age

of iron. The age of savagery is the age of kinship clan, when maternal kinship is held most sacred; the age of barbarism is the age of kinship tribes, when paternal kinship is held most sacred; the age of civilization is the age of nations, when territorial boundaries are held most sacred. The age of savagery is the age of sentence words; the age of barbarism is the age of phrase words; the age of civilization the age of idea words. In savagery, music is only rhythm; in barbarism, it is rhythm and melody; in civilization, it is rhythm, melody and harmony. In savagery, picture-writings are used; in barbarism, hieroglyphics; in civilization, alphabets. In savagery, beast polytheism prevails; in barbarism, nature polytheism; in civilization, monotheism. In savagery, a wolf is an oracular god; in barbarism, it is a howling beast; in civilization, it is a connecting link in systematic zoölogy. In savagery, the powers of nature are feared as evil demons; in barbarism, the powers of nature are worshiped as gods; in civilization, the powers of nature are apprenticed servants. In savagery, men can only count; in barbarism, they have arithmetic; in civilization, they understand geometry. In savagery, the beasts are gods; in barbarism, the gods are men; in civilization, men are *as gods*, knowing good from evil" (From *Barbarism to Civilization*, Amer. Anthropol., I, 1888, pp. 97-123).

SYNTHETIC ESSAYS.

It should be borne in mind that Powell's adoption of a generalized or synthetic style of presentation for the articles here cited and for many others was by no means because he had no command of other styles. He was capable of writing admirable narrative, as was early shown in his famous report on the voyage through the Colorado Canyon. He could present a difficult problem argumentatively and with rare common sense, as is evident from his memorable Report on the Lands of the Arid Regions. He published in much detail the long stories and myths that he gathered with painstaking care from his Indian friends; he set forth in a carefully analyzed form the system of tribal government of the Wyandotte, and he had the patience and perseverance necessary for elaborate induction, as will appear when we consider his monograph on Indian lin-

guistic families. Yet his usual method of writing, especially in his later years, consisted in the synthetic exposition of large problems, without the citation of sources or the mention of particular instances, but with abundant imagery and seemingly overabundant reiteration. It may be well believed that pressure of work was in large measure responsible for these peculiarities of composition. 'He was ever ready to draw off a generous flood from his great reservoir of knowledge, but he had no time to trace the flood back to its spring of supply.'

Powell's liking for generalization had been early shown in his classification of valleys and in his treatment of the broad principle of the baselevel of erosion; but in these two problems he was dealing with inorganic factors, which behave in the same way the world over. In ethnological problems, on the other hand, no one continent affords a sufficient base for all-embracing conclusions of the kind that one frequently meets in Powell's essays; and hence a reader who did not look farther than the printed page might infer that the conclusions there stated were sometimes broader than their foundation. Such a misjudgment would, however, only show that Powell's synthetic style of presentation did not reflect his habitual method of investigation. Most of his essays give no direct indication of the extended observation and the abundant reading on which their conclusions rest, for Powell was a profound believer in the scientific method of investigation, which regards the observation of visible facts as the essential first step in the approach to theoretical inferences as to invisible facts, and which finds in frequent return to observation the only means of verifying the correctness of the theoretical inferences. He had a great confidence in the results thus gained and accepted their guidance wherever they led.

A reader of the synthetic essays may sometimes feel not only that their author does not adduce a sufficient number of facts for the support of the generalizations to which he rapidly rises, but that he not infrequently passes over from induction of generalizations to deduction of consequences from them without giving sufficient notice of his passage. For this reason his essays do not necessarily carry conviction to one who is uninformed of the "patient research by the rigorous methods

of science" that lay behind them. Evidently in such case the failure to carry conviction should not be charged to insufficient investigation on Powell's part, but rather to the condensed form of presentation which he was forced to adopt, alike by his many original ideas which called for expression, and by his many administrative duties that called for execution. The absence of citations may, furthermore, contribute to a feeling that some of his essays are too speculative, for in these modern days of international acquaintance it has become the fashion for an author to give the source and authority of every statement that lies outside of his own responsibility. But Powell did not read French or German, and his method of work did not allow him to follow this fashion, even if he had cared to, and he probably did not care to. He had learned his lesson, and it was the lesson, not the text-book, that interested him. Foot-notes and references to sources are wanting in nearly all of his publications; if he had attempted to cite authorities with any completeness, he would never have had time to finish his work. Hence when one of his addresses presents an evident inference in the form of an observed fact—for example: "The primary and principal source of disagreement among primitive men at the inception of organized society grew out of their desires for the possession of women" (Presidential Address, *Outlines of Sociology, Anthrop. Soc. Wash., I, 1882, p. 116*)—and cites no evidence in support of it, we must understand that the object for which the address was prepared made bibliographic completeness unnecessary, and that the conditions under which it was prepared made such completeness impossible.

Sometimes the inferential nature of adopted conclusions is more explicitly set forth, as in the following extracts regarding the primitive condition of mankind, which form a summary for several paragraphs of more detailed statement: "It will thus be seen that from the five great co-ordinate departments of anthropology, *i. e.*, from somatology, . . . technology, . . . sociology, . . . philology, . . . and philosophy, we arrive at the common conclusion that man was widely scattered throughout the earth at some early period in his history in a very low state of culture; that in such state he

utilized the materials at hand—the loose stones of the earth, the shells stranded on the shores, the broken trunks and branches of trees. . . . And we further discover that he was organized into small tribes, doubtless scattered by every bay and inlet of the seas, along the shores of all the inland lakes, and every bend of the great rivers, and on every creek of the habitable earth. . . . Arts, institutions, languages, and philosophies have therefore a vast multiplicity of origins, and in tracing the outlines of their history we trace the change from multiplicity toward unity” (*Human Evolution*, Trans. Anthropol. Soc. Wash., II, 1883, pp. 181-182). Even in this instance the last sentence falls into the more habitual form of assertion, although with little danger of being misunderstood because of the context.

It must, however, be recognized that in certain other cases the presentation of an inference in the guise of a fact is carried dangerously far. It is very probably true that “attitudes of the body developed into gestures, and sound-making into oral speech, and the active organs of language were specialized, and, finally, oral speech to a large extent superseded gesture speech;” and yet even if true, it is none the less an inference. One may agree that “each minute structure within the body is in part the same as the antecedent structure and in part changed therefrom by the force of impressions from without,” and that “it is in this manner that impressions are recorded, so that the structure itself is a product of all coexistent and antecedent agencies;” but it is a long step then to assert, without qualification: “Out of this arises memory” (*Human Evolution*, Pres. Address, Anthropol. Soc. Wash., II, 1883, pp. 184, 187).

MANNERISMS.

Powell's independence and originality are seen not only in his novel treatment of scientific problems, but also in certain peculiarities of his style in writing. He had a marked liking for unusual words, such as “acculturation” and “intellection.” He seemed to regard the adjective termination, -al, as superfluous; it is retained in the five-syllable adjective of the “United States Geological Survey” because the title of the

Survey was fixed by congressional enactment; but it is dropped from the "Geologic Atlas of the United States" and from the "geologic" and "paleontologic" branches of the Survey, although retained in the "physical" and "chemical" branches. We have already seen that he liked to cast geographical phrases in striking forms; other examples are: "The lightnings that flash athwart the sky," "the coal mine is but a pot of pickled sunbeams," and "then . . . the egg of poetry is laid." He was particularly fond of reiterating a standard phrase-form, in which changes are rung on a variable element: "It is a wonder that the blows of the hammer are transmuted into heat. It is a wonder that the motions of the ether can be transmuted into the rainbow. It is a wonder that the egg can be transmuted into the eagle. It is a wonder that the babe can be transmuted into the sage. It is a wonder that an objective blow can be transmuted into a subjective pain. It is a wonder that the vibrations of the air may be transmuted into melody. It is a wonder that the printed page may be transmuted into visions of the beautiful" (*Human Evolution*, *Trans. Anthropol. Soc. Wash.*, II, p. 208). Reiteration of this kind can hardly have been selected as a thought-saving device, such as makes for the evolution of language; nor would it appear to possess seductive value whereby a reader's attention is enthralled instead of fatigued; it must be regarded as one of those mannerisms by which originality sometimes overreaches itself, for it turns attention to the phrasing rather than to the content of the phrasing.

VIEWS ON EVOLUTION.

Powell was inevitably an evolutionist, fully convinced of the gradual development of the existing order of things from an earlier order. He maintained, however, that organic evolution, as ordinarily understood, should be limited to progress in bodily organs and functions, and that human evolution is progress in culture, in which such phrases as the "struggle for existence" and "the survival of the fittest" have no application. Yet to natural evolutionary processes he ascribed the development of all mental qualities, with their marvelous progress from the lower to the higher, among which "the wonder of

wonders is the transfiguration of selfishness into love" (Human Evolution, Trans. Anthropol. Soc. Wash., II, 1883, p. 208).

He repeatedly returned to the insufficiency of the struggle for existence in human development. "In anthropic combinations the units are men, and men at this stage are no longer passive objects, but active subjects, and instead of man being passively adapted to the environment, he adapts the environment to himself through his activities. This is the essential characteristic of anthropic evolution. Adaptation becomes active instead of passive. . . . It has been shown that man does not compete with the lower animals for existence. In like manner, man does not compete with man for existence; for, by the development of activities, men are interdependent in such a manner that the welfare of one depends upon the welfare of others; and as men discover that welfare must necessarily be mutual, egoism is transmitted into altruism, and moral sentiments are developed which become the guiding principle of mankind. So morality repeals the law of the survival of the fittest in the struggle for existence, and man is thus immeasurably superior to the beast. In animal evolution many are sacrificed for the benefit of the few. Among mankind the welfare of one depends upon the welfare of all, because interdependence has been established" (The three Methods of Evolution, Bull. Phil. Soc. Wash., VI, 1883, XLVIII, 1). Again: "The struggle for existence between human individuals is murder, and the best are not selected thereby. The struggle for existence between bodies of men is warfare, and the best are not selected thereby. The law of natural selection, which Darwin and a host of others have so clearly pointed out as the means by which the progress of animals and plants has been secured, cannot be relied upon to secure the progress of mankind. . . . There are always too many plants born. . . . There are always too many animals born. . . . There are not too many human beings born into the world in lands of the highest civilization, because the earth is not now and never has been filled with men to the limit of its capacity; the great majority are not, therefore, killed off in the struggle for existence, and there is not a small remnant of the best preserved to continue human existence

and secure human progress" (*Competition as a Factor in Human Evolution*, Amer. Anthropol., I, 1888, pp. 303-304).

He continues to insist on this point: "When, during late years, the processes and methods of biotic evolution were clearly set forth by a host of biologists, and the theories successfully applied to all biologic sciences, it was discovered as inevitable that the same laws must apply to man as an animal. But their application was carried beyond the limits of truth. Man, as a being superior to the lower animals, was supposed to have made progress by the same laws—by the survival of the fittest. No error in philosophy could be more disastrous. And yet this statement is widely accepted. . . . In the anthropic kingdom . . . evolution of arts is by invention and the selection of the labor-saving. Evolution of institutions is by invention and the selection of the just. Evolution of language is by invention and the selection of the thought-saving. Evolution of opinions is by invention and selection of the true" (*Human Evolution*, Trans. Anthropol. Soc. Wash., II, 1883, p. 207). "The laws of biotic evolution do not apply to mankind. There are men in the world so overwhelmed with the grandeur and truth of biotic evolution that they actually believe that man is but a two-legged beast whose progress in the world is governed by the same laws as the progress of the serpent or the wolf; and so science is put to shame. . . . That which makes men more than beast is culture. Culture is human evolution—not the development of man as an animal, but the evolution of the human attributes of man. Culture is the product of human endeavor. . . . The old grows into the new, . . . not by natural selection, but by human selection" (*Proc. Amer. Assoc. Adv. Sci.*, xxxviii, 1889, pp. 4, 5).

EVOLUTION OF MUSIC.

In illustration of Powell's mature style, we might select either one of the two addresses before the Anthropological Society of Washington already referred to, one being entitled "From Savagery to Barbarism" (1885) and the other "From Barbarism to Civilization" (1886); but there is another address which exhibits even better his mannerism along with his manner; this is the address on "The Evolution of Music from

Dance to Symphony," which he prepared in 1889 at the mature age of fifty-five years for delivery on as important a public occasion as arrives in the life of an American scientist—namely, on his serving as president of the American Association for the Advancement of Science. In his constrained absence from the meeting of the Association at Toronto, the address was read by his loyal representative, G. K. Gilbert.

The theme of this address was the simple one that "Music . . . becomes by minute increments"—that is, it grows, it evolves. Such a subject might have been presented in the historic order of the discoveries on which the general conclusion is based, with abundant citation of specific examples. Indeed, this order of statement was adopted a few years later by Langley, when he, from the same chair, told in a most charming manner "The History of a Doctrine." Powell's method was altogether different. As usual, he gave no reference to authorities; he did not mention the name of any worker in his field; nor, for that matter, did he present the subject as his own. He marshalled facts and inferences in such order as pleased him for his own purpose, gathering them from the work of other students everywhere. Their variety so evidently exceeded the reach of one observer that it sufficed merely to refer them to "the labors of an army of patient, earnest, keen-visioned investigators." One of the mannerisms of the address was the introduction of long series of similar statements, after the fashion already indicated, apparently with the intention of re-enforcing the lesson that he wished to teach. Thus, in order to emphasize the varied conditions under which savages dance and chant, he wrote: "At the foot of the glaciers they have their homes, and walls of ice echo their chants; by mountain crags they have their homes, and the rocks echo their chants; in valleys they have their homes, and the savannas are filled with their chants; in tropical forests they have their homes, and 'the sounding aisles of the dim woods' ring with their chants." Some of his hearers may have been confused with his abundance of rhetoric; yet such was the richness of his subject that he could not make a short story of it. His beginning is very simple, as if to encourage his hearers; the opening sentence is: "A blue egg may become

a robin;" but in setting forth certain fundamental principles on the second page, he does not hesitate to write: "The third law in biotic evolution is denominated progress in heterogeneity," a statement which probably left some of his hearers behind.

After explaining that musical inventions, but not musicians, show a survival of the fittest, he turns to the adaptation of music to environment: "There is music for the dance and for the battle; music for the wedding and the funeral; music for the theater and the temple, and there is music about everything: the land, the sea, and the air, the valley and the mountain, the flower and the forest, the fountain and the river, the worm and the serpent, the zephyr and the tempest"—thus lavishing instances to the point of redundancy, as if overwhelmed with the wealth of his theme. He next points out that music is one of various arts, each of which was developed from a germ of another nature: "Fetich carving was the germ of sculpture. . . . Picture writing was the germ of painting. . . . Mythology was the germ of the drama. . . . The dance was the germ of music and poetry;" and then, as "sculpture represents material forms in solid matter," and "romance represents biography and history in fictitious tales," so "music represents ideas in sound, by rhythm, melody, harmony, and symphony;" and he thus prepares the way for the question: "How does music grow?" Some have thought it began as a "spontaneous outburst of the human soul in response to the music of the physical and animal world—the sighing of the winds, the murmur of the rills, the roaring of the cataracts, the dash of the waves on the shore, the singing of the forests, the melodies of the birds." Not so. "The objective study of music among the lower tribes of mankind, and among the various people of the world in different stages of culture, . . . leads to a different conclusion." Here the significant words, "objective study," must be dwelt upon; the motive that they suggest is altogether different from that at first suggested by their context, much of which is phrased in so exuberant a style and with such a surfeit of imagined illustrations in place of specific facts that many a hearer might have taken the whole for a flight of fancy unless these calmer words.

"objective study," caught his attention, and led him to perceive that all the imagined illustrations are merely the generalized form of abundant observations.

Although the actual origin of music has nowhere been observed, the "objective study" of the kinds of music found today among primitive people leads inductively to a safe generalization, from which the origin of music in the unobserved past may be reasonably inferred. It began and long continued as a vocal chant, in which the rhythm of sound was adapted to the rhythm of motion in the dance. The chant was at first very simple, but in time the drama came to assist in the development of more varied form. The savage deifies the beast; the stories of animal-gods are dramatized, and the lives that they live are imitated. The eagle "plays among the clouds, rests on the mountain tops, and soars down to circle over the waves of the sea. The humming-bird poises over its blossom cup of nectar like a winged spirit of the rainbow. The deer bounds away through the forest and leaves the hunter lost in amazement. The squirrel climbs the tree and plays about among its branches, and springs from limb to limb and tree to tree, and laughs at the sport. The rattlesnake glides without feet over the rocks, and in his mouth the spirit of death is concealed. The trout lives in the water, and flies up the brook as the hawk flies up the mountain. Dolphins play on the waves as children play on the grass. The spider spins a gossamer web; the grub is transferred into a winged beauty; the bee lays away stores of honey; the butterfly sports in the sunshine like a flower unchained from its stem. The air, the earth, and the waters are peopled with marvelous beings."

At first the human voice chanted alone; then through long ages of savagery and barbarism the chant and the song that grew from it had, for instrumental accompaniment, only the unmusical noise of time markers or "thumpers" of many kinds: instruments of sweet sound are comparatively modern. They came recently, when increasing knowledge of many things led to a contemplation and an understanding of nature. "The human reason has acquired a knowledge of the universe and derived exalted emotions therefrom. The boundless sea now tells its story. From arctic and antarctic lands navies of

icebergs forever sail, to be defeated and overwhelmed by the hot winds of the tropics. The lands with happy valleys and majestic mountains rise from the sea, built by the waves and fashioned by fire and storm. Over all rests the ambient air, moving gently in breezes, rushing madly in winds, and hurling its storms against the hills and mountains of the sea and the hills and mountains of the land. . . . Looking above the earth, the worlds of the universe are presented to view, and their wonders fill the soul. So music has come to be the language of the emotions kindled by the glories of the universe." But this part of the address confessedly advances too rapidly. The higher phases of modern music are European, and Europe, with its civilized peoples, is a part of the world in which Powell was not at home, as he was in the Great West with its savages. It is doubtless true that "as the blue egg becomes a robin, . . . so 'ring-around-a-rosy' becomes a symphony," but the last stages of this evolutionary becoming need another author for their analysis.

INDUCTIVE STUDIES

In contrast to this rhapsodic address, with its imagined examples, its redundant and sometimes extravagant phrasing, and its synthetic treatment, it is desirable to make reference to Powell's inductive work, which is couched in much simpler style. An early example of this kind, already mentioned, is found in an article on "Wyandot government: a short study of tribal society" (First Ann. Rept. Bureau Ethnology, 1881, pp. 59-69); this is a purely objective study of the subdivision of a group of Indians into gentes and phratries, of their method of choosing councillor and chiefs, and of the functions of their civil and military government. It is practically free from inferences and theories of origin, except in a page or two of general remarks clearly separated from the pages of more inductive treatment. Much of Powell's fundamental work seems to have been of this safe kind, but its statement was usually elided in his synthetic addresses.

INDIAN LINGUISTIC FAMILIES.

Assuredly, one of the most important inductive contributions of the Bureau of Ethnology to science is the monograph on "Indian linguistic families," which, with the accompanying map of North America, exclusive of Mexico, was published in the Seventh Annual Report of the Bureau of Ethnology (1891). The idea of such a monograph, accompanied by a linguistic map, had been in Powell's mind for many years, but, owing to the pressure of his manifold duties, its final planning and execution was intrusted to his associate, Mr. H. W. Henshaw, then in charge of the Bureau under him. Gallatin had published a North American linguistic map in 1836; but the Bureau map was based on a much larger body of material, and followed Powell's own idea of lexic, not grammatic, classification—that is, linguistic relationship was determined for the Indian languages by similarities between single words, not by resemblances in the construction of genders and tenses. This treatment was adopted because word-roots were believed to be the most permanent elements of language, while grammatic structure is but a changing phase. Indian languages to the number of several hundred thus analyzed and compared were grouped in stocks or families, the members of each of which show fundamental lexic similarities believed to be inherited from a common ancestral speech, while the different stocks show no relationship whatever. During the long progress of this work some languages were set apart which had at first been placed together, and others were brought together after having been at first separated; but in the end no fewer than fifty-eight stocks were distinguished, all fundamentally different, not as French is from German, but as French and German are from Arabic and Hebrew; for each stock includes a group of languages, and the languages of some stocks are as diverse as the Indo-European tongues. The areas occupied by the stocks in their primitive distribution are represented by colors on the map, and the results thus graphically shown are very striking. First to be noted is the rarity of intermixed or fragmentary color areas; second is the extraordinary contrast between the great extent of the areas of the Algonquian and

Athabascan stocks and the small-scale patchwork of the stocks in the Coast ranges of California. While neither Powell nor his associates regarded the map as final, it was accepted as a sufficient base for several important inferences, among them that the aboriginal tribes had long been sedentary and not nomadic, as some ethnologists have supposed, for if nomadic the linguistic areas should show more overlapping and intermingling than is actually the case. It is only in view of this conclusion that the small areas of the California stocks can be understood, and even then it cannot be understood easily; for however sedentary the tribes of northern California have been, it is difficult indeed to believe that they represent complete linguistic independence in closely contiguous areas of moderate relief, without resemblances by inheritance or by short-distance intermixture. Recent studies indeed suggest that a way out of this quandary may be found by grouping together certain stocks which Powell regarded as wholly independent; but whatever changes may be made in the original map, it was a great contribution to the science of American linguistics.

PHILOSOPHICAL STUDIES.

Powell's interest in philosophical studies was early developed and long continued; as one of his friends said: "He drank deep at the perennial fount of classic philosophy . . . and had constant reference to the courses followed by the pioneers of definite thought about the east shore of the Mediterranean." It is therefore interesting to quote his three definitions of this elusive subject written in the early '80's. "Philosophy is the explanation of the phenomena of the universe" (*Philosophical Bearings of Darwinism*, Washington, 1882); "Philosophy is the science of opinion" (*Three Methods of Evolution*, *Bull. Phil. Soc. Wash.*, VI, 1883, p. xxx); and "A philosophy is a system of opinions concerning the phenomena of the universe, which the people entertaining such opinions have observed" (*Human Evolution*, *Trans. Anthropol. Soc. Wash.*, II, 1883, p. 181). How significant it is that the emphasis is shifted from the objective phenomena of the universe in the first definition to the subjective science of opinion in the second, and that the single science of opinion suggested in the

second definition should be replaced by an implied multitude of such sciences in the third!

Powell's epigrammatic rendering of the contrast between the philosophies of savagery and civilization have already been quoted. He naturally found little value in metaphysics, which he rightly viewed as the very opposite of science, and hence erroneous. "The error of the metaphysic philosophy," he said, "was the assumption that the great truths (or "major propositions") were already known by mankind, and that by the proper use of the logical machine all minor truths could be discovered and all errors eliminated from philosophy." On the contrary: "It is found that in the course of the evolution of mind minor propositions are discovered first, and major propositions are reached only by the combination of minor propositions; that always in the search for truth the minor proposition comes first, and that no major proposition can ever be accepted until the minor propositions included therein have been demonstrated. . . . As the metaphysic methods of reasoning were wrong, metaphysic philosophies were false; the body of metaphysic philosophy is a phantasmagoria" (*The Philosophic Bearings of Darwinism*, p. 6).

During the earlier years in which these passages were written, Powell's philosophical studies were subordinate to his work in ethnology. In later years philosophy came to have a more dominant interest, and at times so fully occupied his thoughts that in a lecture of apparent ethnological content, as indicated by its title, "Relation of primitive people to environment, illustrated by American examples" (*Smithsonian Institution, Report 1895*, pp. 625-637), he devoted a good share of his hour to an abstract consideration of the difference between "quality" and "property." It was in these later years that he sought, as others had done before him, to establish a fully logical foundation for mechanics, and reached the conclusion that motion, either molar or molecular, is constant in quantity, but may be deflected in direction; but his use of words in this connection was sometimes such that it was not easy to follow his meaning; he wrote, for example: "When motion becomes energy, then speed becomes inertia, and path becomes velocity;" and "When time becomes causation, then persistence becomes

state, and change becomes event" (Bureau of Ethnol., 19th Ann. Rep., 1900, pp. LVI, LVII). In another direction, he went so far as to conceive consciousness as one of the primary attributes of the particle: it would seem here as if, in the effort to know the unknown, he had reverted from the philosophy of civilization to that of savagery; it is indeed curious to find that one long practiced in observational sciences, and who had years before recognized the necessarily large subjective element in all philosophies, should at last persuade himself that, in a matter so recondite as the primary attributes of the particle, his mental concepts were really the true counterparts of external nature, from however much cogitation they had sprung.

PENTALOGIC SERIES.

During the eight years that elapsed between Powell's resignation from the directorship of the Geological Survey in 1894 and his death in 1902, a subject that attracted him greatly was the study of human activities—familiar matters for the most part, so that his explicit statement of them sometimes seemed like the unnecessary formulation of the common-place—but his object here must have been to bring even familiar matters to conscious attention, and to discover in them their essential and wonderful nature, especially wonderful when they are viewed as products of long-continued evolution. It was as if Powell wished to arouse us from our indifference to everyday affairs, and to place them objectively in the great procession of the world's march, with all the dignity belonging to their ancient origin. Such seem to be the motives underlying his study of the "pentalogic series of human activities," in which he classed everything connected with man's "pleasures, industries, institutions, languages, and opinions." He saw that the study of these activities gave rise to five sciences, "esthetology, technology, sociology, philology, and sophiology," each of which is again divided; for example, sophiology, or the science of instruction, contains five arts—"nurture, oratory, education, publication, and research." So fully was Powell convinced of the value of his pentalogic scheme, that for a time his administrative reports on the investigations conducted

in the Bureau of Ethnology were divided according to it, although this required the division of one man's work under different headings.

TRUTH AND ERROR.

Reflection upon these broad subjects seems to have developed the ambition to systematize all accumulated knowledge and philosophies, from those of the savage and lower barbarian to those of the modern scientific world, thus "framing a cosmic compendium at once broader and simpler than any previously conceived." He was in this way carried from the concrete study of human races to the more and more abstract study of human thought. The field that he sought to cover was more extensive than any that he had previously cultivated, and it is to be questioned whether so vast an ambition was not less a sign of continued strength than of approaching weakness. He planned to arrange the entire content of knowledge in a system of three parts, the first to deal with Nature, the second with Man, and the third with Mind; and with a view to giving his results a "general, and hence permanent, character, the work was given the form of a trilogy," and was "modeled after artistic rather than technical standards." The first part of this heavy undertaking was published under the title of "Truth and Error; or, the science of intellection" (1898); the second part appeared in a series of papers in the *American Anthropologist*, having for titles the names of the pentalogic series given above, and designed for reprinting with additions under the name of "Good and Evil." The third part was left unfinished.

A devotedly loyal disciple of Powell's says of this work: "The breadth and depth of its foundations were little realized by co-workers, still less by the critics of the preliminary essays; indeed, the modesty of the author seldom permitted him to see in its full magnitude the mighty task to which he was impelled by the same powerful instinct that inspired his military and exploratory efforts;" but the same disciple went so far in eulogizing his master that we must prefer the estimate of another of Powell's intimates, a man of more even

balance, who formed his judgment without overweight of admiration, and who wrote of his friend: "His philosophic writings belong to a field in which thought has ever found language inadequate, and are for the present, so far as may be judged from reviews of 'Truth and Error,' largely misunderstood. Admitting myself to be one of those who fail to understand much of his philosophy, I do not therefore condemn it as worthless, for in other fields of his thought events have proved that he was not visionary, but merely in advance of his time."

It is sad to close the record of an earnest life with an account of plans unfinished and unfinishable, rather than with a record of labors brought to a well-rounded close; it is sadder still to follow a leader to a point where his leading is not followed—where his latest thoughts, instead of remaining the inspiration and foundation of new studies, are passed over in silence by the generation that follows him. But for these reflections there are two consolations: one is the contemplation of the great and enduring work that the leader accomplished in years of fuller strength, and of that some record is here set forth; the other is the loving memory in which he is held by his many friends. Two of these may here speak, as they did at a meeting commemorative of Powell's services, held under the auspices of the Washington Academy of Sciences on February 16, 1903.

PERSONAL ESTIMATES.

Powell's long-time friend and trusted fellow-worker, G. K. Gilbert, from whose address the last preceding quotation is taken, said also: "The glow of his enthusiasm, the illumination of his broad philosophy, the warmth of his friendship, are still with us, and we should be either more or less than human to divest ourselves so soon of the influence of his inspiring personality. It was through this personality, too, that he accomplished much of his work for science. Gathering about him the ablest men he could secure, he was yet always the intellectual leader, and few of his colleagues could withstand the influence of his master mind. Phenomenally fertile in ideas, he was absolutely free in their communication, with the result

that many of his suggestions—a number which never can be known—were unconsciously appropriated by his associates and incorporated in their published results. . . . The scientific product which he directly and indirectly inspired may equal, or even exceed, that which stands in his own name.”

The Secretary of the Smithsonian Institution, S. P. Langley, spoke of Powell in part as follows: “Wherever I have been with him, in whatever surroundings, I think I have been more impressed with the simplicity and self-comprised nature of his character than even with the complexity of his knowledge and achievement. He was to me not so much one of the common figures of daily life, as one of Plutarch’s men. . . . Sincere he was, and truthful to the point of being unable to bring himself to hint the thing which is not, nor even to allow the shadow of deceit in his ways. Such sincerity existing in his own heart, begat a confidence in others which did not always meet its just return. . . . He was a generous man, kind to others and helpful; a combative and a brave, and always a self-contained man, who found in himself counsel sufficient for his need. . . . He was a truthful and steadfast man, and one who never deserted a friend.”

Powell died at his summer home at Haven, Maine, on September 23, 1902, in his sixty-ninth year.



Chas. A. Schott

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CHARLES ANTHONY SCHOTT.

It is inevitable that those to whom is vouchsafed a long life of usefulness should outlive the friends of their youth. One who would at this late day speak of the early life of our colleague, CHARLES ANTHONY SCHOTT, will find that his life was wholly devoted to the work of the Coast Survey. His companions of those days have passed away; were they living we cannot doubt that they would give one universal testimony. The indefatigable Bache would recall his own visit to Germany in 1836-1838, his inquiry into the condition of scientific education, and his eventual report thereon. He would recall an interview with Gauss and his account of the geodetic and magnetic work in which that gifted man was interested. He would recall that he had himself visited the Polytechnic School at Carlsruhe and knew that any graduate from that institution, where Schott began study three years later, would be a desirable addition to America and to the Girard College that was then uppermost in his mind. He would tell us of Humboldt, of Sabine, of Bessel at Königsburg, of Struve at Dorpat, and of the great works they were doing for the benefit of the world. Bache esteemed highly the educators and the scientists of Europe and did not hesitate to employ both in American works.

It is not a light matter to properly depict the strength and work of one who, like Carl Anton Schott, left the impress of his own character and of his example on every detail of such a great national undertaking as our Coast and Geodetic Survey, and equally so on every man associated with him in the prosecution of the work of the Survey. As a great man's influence never ends, so also there is no definite finality, no end, to a great survey; it runs along for centuries, ever responsive to the strain of the increasing needs of a growing population and an enlarging domain. Granting that we must protect our shipping by surveying, mapping, and guarding our coasts; that we must map our interior lands to keep up with increasing business enterprises, and that we must do this with every new addition to our possessions; it follows that the Survey becomes one of

our permanent institutions, essential to our prosperity. It must increase in thoroughness, efficiency, and expense so long as our Republic preserves its vitality and energy. Its activity must penetrate into every branch of knowledge and into every new path of exploration.

We vividly realize the pleasure it must have given Schott, from his youth onward to old age, to take such an important part for over 50 years in framing the fundamental organization of the Survey and its attendant geodesy. From his early education at Carlsruhe as a civil engineer, and from his first employment, at the age of 22, by Bache, he appreciated the importance of a thorough knowledge of field work as well as office work; his own activities in every line of work have served as ideals for hundreds of expert assistants. The hydrography of harbors, channels, rivers, and oceans, the details of the minute accuracy of base-line measurements, the sources of errors in geodetic triangles, the methods of determining astronomical latitudes and longitudes, the methods of hypsometric determinations, the errors of magnetic and pendulum apparatus, were all known and appreciated and many of them greatly improved by him, to say nothing of the effective systematization introduced by him into all computations and office work.

Schott's six years of study at the Carlsruhe Polytechnic afforded him the basis for his life work. His early years were spent in helping Bache to lay solid foundations for the structure that was to bring honor to all engaged upon it. He brought to us from Germany those abilities and tendencies that by inheritance and education characterize the great German nation, to which we are ourselves so closely related. European civilization has developed innumerable peculiarities, characteristic of nations, families, localities, and the progress of the age. These have been brought across the Atlantic from Europe to America with each successive wave of migration. The ideal example set before us by Schott, his energy, adaptiveness, perseverance, both intellectual and physical, his love of home, drawing, painting, and mathematical precision, are to be held as most precious characteristics.

Our colleague was born at Mannheim on the Rhine, in the Duchy of Baden, August 7, 1826, the oldest son of Anton Carl

Schott and Anna Maria Hoffmann. The inheritance of some property by the mother sufficed to insure the comfort of the family during the succeeding years. The happiness of the child at home is well assured by a glance at the sweet little "new year's poem" read by him on January 1, 1833, as a tribute to his parents on that annual holiday. "To your faithfulness alone I owe my happiness" is the prevailing sentiment that pervades his lines. Many years later, when his own children begged for some sketch of his early life, he wrote a page or two from which I am allowed to quote:

AUTOBIOGRAPHY OF THE EARLY LIFE OF CHARLES ANTHONY SCHOTT.

"As the most momentous question in any biographical sketch is that of birth, I begin with that event, which happened to me on August 7, 1826, at Mannheim, in the Duchy of Baden, at the confluence of the Neckar and the Rhine. My parents belonged to the middle class, my father being a merchant, the son of a judge, who left him no fortune in consequence of the Napoleonic wars, which were particularly hard on the inhabitants of the Rhine provinces. My mother, however, being an heiress, placed us in comfortable circumstances.

"It was stipulated at the marriage of my parents that any children that might be born should be reared in the Lutheran faith. Although my father was christened in the Catholic church he was nevertheless a man of free thought. All religious ideas that I ever had were due to my mother's influence. I had two sisters and one brother, my sister Anna being the only one who lived to old age.

"My earliest recollection is of my crying on being unable to open my eyes one morning, they being glued together. My second, a walk across the market-place with my parents. We met an acquaintance who asked me, 'How old are you?' My mother told me to say, 'I am in my third year.' My first memory of school days is learning to read my letters from a book spread on the teacher's lap. Sitting one day in a big arm-chair, one of my parents asked me, 'Karl, do you want to go to school?' I said, 'Yes,' and was promptly sent to the free public school, being then six years old. Here I was taught the rudimentary studies—reading, writing, spelling, arithmetic, and a little geography—for three years. At this time we had a French governess at home to drill us in the French language.

"At the age of ten or eleven I entered the Lyceum or classical school at Mannheim, where I was pestered with Latin for four years and one year with Greek, to my great disgust, as I had more aptitude and keen sense for natural history. Beside the classics we had mathematics, natural history, geography, and, the last year, rudiments of physics, but no teaching in other language than the German and no history except the

ancient. The whole plan of the Lyceum was conducted with the idea of cutting off all liberal thought and severing all connection between Roman and Greek history and modern history. One redeeming feature was the admittance of some athletic sports. Attendance on religious instruction was compulsory, with an effect only skin deep. That I must have had something of an inquisitive mind I infer from the fact that my schoolmates nicknamed me '*Vir doctus*.'

"Having shown some talent and inclination for mechanics and an eagerness for scientific study, my father determined to send me to the Polytechnic School at Carlsruhe, in 1840, to perfect myself in civil engineering. For the first two years I was placed in the home of the professor who had charge of the physical laboratory, where I laid the foundation of experimental inquiries. Here I received a stimulus and became conscious of a desire and capacity for serious work. I enjoyed the utmost freedom as to the workings of my own mind, absorbing with intense interest not only the multifarious topics taught, but making independent investigations and associating myself with kindred minds for pursuit of other knowledge, especially the rudiments of astronomy, for which at that time no chair existed. With a small hand telescope, a home-made sun dial, and a star chart, I acquired some knowledge of the constellations, and with the help of Littrow & Bode's '*Astronomy*' I was enabled to compute lunar and solar eclipses, to my intense gratification. I here also learned to handle magnetic instruments, to which in later life I devoted much time.

"The three preparatory departments of the Polytechnic were successfully passed, and the last three years were devoted especially to engineering, so I graduated at the age of 20 as civil engineer of Baden. Of six graduates I came out as number 2 of the class of 1847. These six years at Carlsruhe I reckon among the most pleasant of my life, making frequent excursions on foot through the Vosges Mountains and the Schwarzwald, gratifying also my love for drawing and sketching. Later I penetrated into Switzerland and upper Italy, Lombardy, Milan, and Venice, also visiting the art galleries of Munich to study their treasures.

"I expected soon to enter the service of the State, as the railroad development at that time required engineering ability; but in this I was disappointed, owing to the great political agitation for freedom in Germany, known as the revolution of 1848. After shouldering a musket for a short time in the liberal ranks, and not finding military life congenial, and seeing no early chance of making a living, I obtained leave of absence from the State to visit the United States, with a view of perfecting myself in my profession. About this time my father met with reverses in business, and had the misfortune to become blind; this forced me to rely upon my own resources.

"With about \$150, I set out for America, in June, 1848, at the age of 21."

As above stated, and after serving the State for a year, Schott obtained leave of absence, in 1848, to visit the United States, "with a view of perfecting myself in my profession," as he says. But if he entered our Survey with the idea that it was only a temporary employment, and that he should eventually return to Mannheim, he was very happily disappointed, for he never left its service. Eventually he became a naturalized citizen of the United States. He served our Government and the Coast Survey to the day of his death, July 31, 1901, a little less than 53 years.

His voyage, starting from Mannheim on Thursday, June 15, and ending in New York City on Tuesday, August 8, 1848, is fully narrated in a daily journal still preserved by his family and which I have been permitted to inspect. This journal is full of remarks bearing upon such matters as a most intelligent engineer and student would be likely to note, notwithstanding the great difficulties under which he labored, in company with many others, on an English sailing ship of about 1,500 tons. The vessel is spoken of as the *Prince Albert of London*, and it progressed under sail very slowly. He gives an interesting analysis of the psychological phenomena attending the four movements of the ship "lengthwise, crosswise, vertically, and twisting for two days and three nights; and I have scarcely any seasickness, but a slight headache." "Smoking and the cloudy weather of the English Channel produce no seasickness like that of English passengers who eat much meat; but now and then a thought of homesickness." He gives many suggestions with regard to the provisions that each passenger must provide for himself or else buy of the ship's cook. He is particularly interested in the navigation of the vessel, the sextant observations for latitude and longitude, the currents of the water in the ocean, the variety of birds above the ocean, and the animal life in the ocean, of which he writes like a young naturalist on his first voyage of discovery. Undoubtedly, the journal was written for transmission to his parents and must have furnished the basis for many interesting letters. Those were the days preceding regular steamship navigation across the Atlantic, but he had seen something of steamboats on the Rhine. His steamboat experience of 24 hours from Rotterdam

to London (June 20, noon, to June 21) on the *Batavia*, with colossal engines of 200 horsepower, had given opportunity for many personal experiences. To him "London seems smoked like a ham in a chimney and is thoroughly unpleasant to me as a residence." The captain of the *Prince Albert* sailed slightly south of New York, against the Jersey coasts, where he was becalmed, "so that we should not have arrived for two days longer had it not been for a steamer that picked us up 40 miles from New York." What a contrast between the present days and those when, as he says, "we passed the quarantine, and at a short distance from the city the luggage was examined, but in a very superficial manner, so that one might smuggle as much as one wished." He had had a premonition that he should arrive on the twenty-second anniversary of his birthday, and doubtless he wished it to be so, for his journal concludes with the words, "Now that I have safely arrived, may my other wishes also soon be realized."

Having landed in New York August 8, 1848, but scantily provided with money and conscious of the failing strength of his father, we feel assured that Schott must have found some temporary employment, being thrown upon his own resources while looking about for an opening in his profession as engineer. It is said, on credible authority, that Schott came with letters of introduction to a very distinguished countryman and compatriot, Theodore E. Hilgard,* of Zweibrücken, the ducal city of the Palatinate, not far from Mannheim, and which after various vicissitudes had been returned to Bavaria as a part of her possessions by the Treaty of Luneville about 1814. He was an eminent German jurist and author, who had migrated to America and settled with his family, in 1835, on the

* Theodore E. Hilgard, the father of J. E. Hilgard, was the cousin of Gustavus Hilgard; the latter was the father of Ferdinand Heinrich Gustav Hilgard, who was born at Speyer in 1835 and educated at Zweibrücken and Munich. Emigrating from the latter city, he stayed for a while with his grand-uncle, Theodore, near Belleville. Eventually Ferdinand became famous under his adopted name as Henry Villard, the American journalist and financier, who died in 1900. The students of eugenics will be interested to know that from the single grandparent in Zweibrücken (Jacob Hilgard and Marie Dorothea Engelmann) there descended men of such eminent ability as Theodore E., born 1800; Gus-

prairie near Belleville, Saint Clair County, Illinois, when his eldest son, Julius Erasmus Hilgard, was 10 years old. The son removed to Philadelphia in 1843, at the age of 18, to pursue the study of civil engineering. Here he became acquainted with Bache, who had been appointed Superintendent of the Coast Survey in 1845 and who soon added J. E. Hilgard to his civilian force. Doubtless it was through Hilgard that Schott was brought to the notice of Bache and into the service of the Coast Survey, his appointment dating from December 8, 1848. At that time Bache, the Superintendent, at the age of 37, Hilgard at 23, and Schott at 22, formed a trio of young men by whom the Survey was to be moulded into its present shape.

Should we not stop a minute to consider and compare Bache, the organizer of men; Hilgard, the man of affairs; Schott, the adviser and computer in great geodetic operations.

The most prominent trait in the life of that gifted man, Alexander Dallas Bache, was his wisdom and ability in calling to himself and holding the great body of men needed to do his work in the best possible manner. The reorganization of the Survey, in 1843, was but a natural culmination of his early work as chemist in the University of Pennsylvania and his work as educator in Girard College. He had a perfect appreciation not only of the needs of the Survey, but of the character of the American people. He inherited the ability and wisdom of his grandsire, Benjamin Franklin; he had been trained in the discipline and traditions of West Point; he was devoted to exact science and an authority on everything bearing on education. Thrown into daily contact with the ablest men in every department of life, gifted with unusual geniality, acceptable to every element in American society, he gathered together the army, the navy, the civilians and the scientists, the beginners

tavus, distinguished in law; Julius E., born 1825, distinguished in physics; Theodore, born 1828, professor at the University of Munich; Heinrich Villard, born 1835, the financier; Eugene Waldemar, born 1833, the American geologist and chemist, and finally Otto Hilgard Tittmann, the son of Rosa Hilgard, born at Belleville in 1850, who entered the Coast Survey in 1867 and has been its Superintendent since 1901. Dr. George Engelmann, the botanist of St. Louis, and his cousin, J. E. Hilgard, the physicist, were among the founders of our National Academy of Sciences.

and the experts into one harmonious mass of active workers, among whom none were more enthusiastic and active than Hilgard and Schott.

After spending a few months in New York, Schott appears to have applied for work under Bache, or rather with Hilgard, who was just a year older than himself and had had analogous education, but not quite so much severe training. They were equally industrious and enthusiastic, and from that time onward were closely associated in all the work of the Survey until the resignation of Hilgard in 1885. Bache always praised them both for these same qualities; but as Hilgard developed in the humanities, while Schott devoted his whole thought to the intricacies of the fundamental geodetic operations, therefore Bache, as General Superintendent, soon perceived that Schott, as a trained engineer, mathematical geodesist, and clear-headed magnetist, was the man to whose hands all intricate calculations could be safely intrusted. Thus it came about that long after the death of Bache (February 17, 1867) the computing division, the vital heart and vivifying blood of the whole Survey, continued to receive the impress of Schott's sturdy character, his thoroughness, honesty, modesty, fairness, perseverance, persistent search for error.

Are not these traits the natural results of the habit of thought incidental to a thorough university training? In the delightful days of college life and university life it is the senior professor whose kindly words do honor to himself and his students also by public recognition of the merits of the young candidates for university degrees. The encouragement and stimulus thus given to a modest young man in his long search after the hidden truths of nature is the most admirable feature of student life. It was this that gained the devotion and love of many a student of Neumann, Bessel, Struve, in the early days when Germany was teaching the world that her strength lay in the fullest recognition of every man's originality and ability. Her query was, "Whose brain thought of this? Show me the man." It was this spirit of good work and full credit that filled the air at Mannheim and Karlsruhe in those troubled days of 1848. Those were the days that tried men's souls in Germany. My own revered instructor, General Koerner, of

the College of the City of New York, was one of the many then expatriated, and fortunate it was for me that, in 1850, in New York he found employment for his talents in descriptive geometry. No wonder that Schott left Mannheim to find peace and work in the new world.

A beautiful testimony to Schott's character and influence in life was summed up in the mortuary tribute expressed by his associates on August 1, 1901:

"He was enthusiastic, faithful, and diligent in all duties he was called upon to perform, and through his learning and probity earned a reputation extending over two continents which is most worthy of emulation. Conscientious and expert in his specialties—geodesy and terrestrial magnetism—his labors added immeasurably to the reputation of the Bureau and of his comrades who gathered the material he so ably discussed. The methods of computation now in use in the Bureau are an indelible record of his ability. His high ideals of duty and his tireless and persistent striving for them, made him stand forth as a noble example of the best type of public official, and his uniform kindliness endeared him to those who knew him as a friend."

BIBLIOGRAPHY.

It will be profitable to consider in detail some of Schott's works. These are mostly official publications of the Coast Survey and are enumerated in detail in the appended bibliography, for which we have to thank Mr. Ralph M. Brown, the Librarian of the Coast and Geodetic Survey. We have arranged the titles chronologically in order that one may follow the steady development of the broad system of study that Mr. Schott maintained during his lifetime. It is to be noted that the natural quietness and the perfect modesty of our colleague rarely allowed him to read any special memoir in public. His life was one of quiet thought and labor; his best judgment was daily called forth in matters of the highest precision; he was the best of advisers, but not given to public expositions or popular display. Having become a citizen among us, having entered the congenial service of Bache and his adopted country, he remained in continuous service from December, 1848, to July, 1901. These 53 years, through many changes of administration, enabled him to carry to perfection a great systematic work; he was our ultimate authority during his life-

time in matters relating to geodesy, terrestrial magnetism, practical astronomy, standards of length, hypsometry, and climatology. Probably no one in this country has covered so wide a range of close study, accurate knowledge, and laborious computation. The list of his publications constitutes an impressive monument, built of his own works, better than a marble cenotaph raised to his memory.

HYDROGRAPHY AND OFFICE WORK.

The first practical problems of the United States relative to the coast consisted in determining the locations of dangers to navigation, such as rocks, shoals, and the treacherous currents due to winds and tides. Schott's attention had been drawn to this subject first when he left Rotterdam and sailed from London along the shores of Kent and through the English Channel, and again when he skirted the American coast of New Jersey northward to New York. These were his first experiences in oceanic coastal waters. He was quick to perceive the sources of danger, and asked Bache that his official duties might include hydrographic service as well as office work in Washington.

The first office buildings of the Coast Survey were in some old residences adapted to office work, on the southerly slope of Capitol Hill, adjacent to the residence of Daniel Carroll, of Duddington. They are now replaced by Government structures. The delightful southeasterly breeze of summer was in those days filled with mosquitos and malaria from the canals and marshes, but the progress of recent years has removed the canals and marshes and other objectionable features. The shambles and slave-pens, the old railroads, the telegraph poles, the surface drains, the yellow fever and the cholera of 1830-1860 have given place to our model city of the present century.

In those days it was a physical relief and an intellectual advantage to escape from office work in the summer months and devote that season to the field work and the pure air implied in hydrography and geodesy. Both Bache and all of his assistants profited by such summer months of field work. The semi-annual transfers of duty from Washington northward or southward, or even from the Atlantic to the Pacific coasts, became an important hygienic feature in the office work. Thus

it was that in the very beginning Schott was assigned as occasion demanded, alternating between hydrography, geodesy, and the computing division. After his first assignment, in 1848, to the latter division he was soon drawn away, namely, October, 1849, to hydrographic work in Albemarle Sound and Mobile Bay, under Commander James Alden. In August, 1861, he made the survey of Casco Bay, and in 1863 determined the location of all the fortresses or earthworks thrown up for the defenses of the city of Washington.

THE COMPUTING DIVISION.

Early in Schott's official life Bache had perceived his special fitness for extensive geodetic computations. For some years the computing division was officially in charge of Schott only during the absence of J. E. Hilgard; but the gradual extension of the work and his evident fitness brought about a reorganization, in 1854, and on July 1, 1855, Schott became wholly responsible for this division and so remained for 45 years. Bache realized the absolute dependence of the Survey upon men thoroughly trained in both mental work and physical work—the sound mind in the sound body. Such men as A. A. Humphreys, of West Point; James Alden, of the Navy; Sears C. Walker, among the astronomers; C. A. Schott, of the Polytechnic School; he could always rely on implicitly. He seemed instinctively to know where to look for his assistants and whom to choose. In his annual report of 1848, page 57, Bache says:

“A superficial examination of the subject, or the taking for granted of a prescribed routine, is apt to impress one with notions of the great accuracy of results in which are concealed constant errors of grave importance. Turning up the surface develops these concealed errors and leads to scientific discovery. The action of different minds accelerates the progress of truth, and on this account I have published a paper of Assistant Sears C. Walker.” . . .

It was by “turning up the surface” that Walker discovered, in 1847, the old observations of Neptune by Lalande, on May 16, 1795.

In his report of 1850 Bache says that George Davidson, H. M. Harrison, James S. Lawson, and John Russell, in April,

1850, "volunteered to serve in any extremity and in any duty, however hard or manual, relating to the survey of the coast of California." This was his way of securing men who proved their faithfulness during many subsequent years. This was the beginning of the California surveys and the strenuous rush work of 1850. The extension of the Survey to the Pacific coast made it necessary for Schott to be called in, on July 18, 1850, from his hydrographic work under James Alden, and brought about a more detailed organization of all office work. Probably the first evidence of his genius consisted in his comparison, during 1848 and 1849, of the first and second sets of computations of the observations for latitude with the zenith telescope, at the station Unkonoonuc, for the method was novel and the sources of instrumental error as yet unknown.

Every successive annual report of the chief bears witness to the steadily increasing impression made upon all by his genius and his work. Thus, in 1851, page 93, Bache says:

"He has great aptitude for scientific investigations, whether pertaining to astronomical, magnetic, geodetic, or hydrographic subjects, and his zeal and industry are fully equal to his ability."

Again, in his report for 1853, on pages 8 and 9, he writes:

"The computing department of the office has attained a position of efficiency worthy of all praise, and of special mention in enumerating the permanent results of the work, though this has been due not to the efforts of one, but of many years, combined with remarkable zeal and assiduity directed by clear intellect and ample knowledge."

Bache kept the personal acquaintance and oversight of every man; neither navy, nor army, nor civilian, nor scientific alone, but each and all together. In the report for 1854 Bache agrees with Captain Benham, who was then in charge of the office, that "the computing division is an excellent organization, the most regular, efficient, and economical of any of the branches of the office." On July 1, 1855, Schott was made chief of the computing division and his colleague, Hilgard, soon became chief of the office work in general. In connection with successive increases in salary, which are generally accompanied by a few words of commendation, we find, on page 155 of the report for 1858, Bache says:

CHARLES ANTHONY SCHOTT—ABBE

"I agree with Palmer, in charge of the office, that the ability, industry, and strict attention to duty that characterize the chief of the computing division are rarely equalled. His health suffers from the confinement to which his duties have subjected him."

The successive appointments and responsibilities which came to Schott are here brought together:

- 1848, Dec. 6. Appointed in the Coast Survey at \$25 per month and assigned to computing division.
- 1849, April —. Assigned as hydrographic draftsman under Lieut. James Alden to the schooner *J. Y. Mason*, operating in Albatraz Sound.
- 1850, do. do. Operating in Mobile Bay.
- 1850, July 17. Returned to the computing division.
- 1853, Dec. 3. Received naturalization papers as an American citizen.
- 1854, Jan. 1. Marriage to Teresa Gildermeister at Washington, D. C.
- 1855, July 1. Appointed chief of computing division, Coast Survey.
- 1861, Aug.-Oct. In charge of the schooner *Joseph Henry*, making hydrographic survey of Casco Bay, Maine.
- 1862, ———. [Hires a negro as his substitute for army service during the Civil War. The Royal Society of London sends him a letter of thanks for his reduction of tidal observations in the Arctic Seas made by Elijah Kent Kane.]
- 1863, ———. [By request of Major Barnard he determined the positions of the fortifications erected in defense of Washington. September 28, date of marriage to Bertha Gildermeister at Prairie Home, Illinois.]
- 1869, Jan. 1. Conducted a party to Illinois to observe total eclipse of the sun.
- 1870, ———. Sent to Catania, Sicily, as a member of the Superintendent's party to observe total eclipse of the sun.
- 1871, ———. A founder of the Philosophical Society of Washington.
- 1872, ———. Elected a member of the National Academy of Sciences.
- 1874, ———. Made a member and Fellow of the American Association for the Advancement of Science.
- 1896, ———. Made a member of the Sociedad Científico Antonio, Alcala, Mexico.
- 1898, ———. Represented the Coast and Geodetic Survey at International Conference on Terrestrial Magnetism at Bristol, England.
- 1898, ———. Made a member of Washington Academy of Sciences.
- 1898, ———. Awarded the Wilde Prize by the French Academy of Sciences.
- 1899, Feb. 4. Wilde Prize delivered by President McKinley in person.

- 1899, Dec. 31. Relieved from duty as Chief of Computing Division and assigned to charge of computation of arc measures.
 1900, ———. Transcontinental Triangulation, etc., published.
 1901, ———. The manuscript of the Eastern Oblique Arc completed.
 1901, July 31. Died at Washington, D. C.

LONGITUDE AND LATITUDE.

Among the many innovations on methods that were formerly in use in Europe, one of the first to be encouraged by Schott and adopted by the Coast Survey was the so-called American method of recording by chronograph the observations made with the astronomical transit. Then quickly followed the application of this method to the determination of differences of longitude by the use of the Morse system of electro-magnetic telegraph. It would seem that crude forms of chronograph, with the complementary appliances added to the astronomical clock, were first devised by O. M. Mitchell, founder of the observatory at Cincinnati, his assistant, Mr. Twitchell, and his friend, Professor Locke, all of Cincinnati; but these were soon replaced by the Bond spring-governor. The gifted Sear C. Walker,* one of the first men secured by Bache for assistant in the Coast Survey, in 1847, was in charge of all longitude work until his death, in 1853. To Walker we owe the rapid development of this new American method of determining longitudes, which was subsequently perfected by our late colleague, Benjamin Apthorp Gould. To Mr. Schott fell the special duty of adjusting these most accurate longitudes into a homoneous system. His report on the telegraphic longitude network of the United States and its connection with that of Europe by cable gave us the best results on that subject that we could have at that date. The recent application of radio-electric waves to the same purpose seems also to have been first tried by the Coast and Geodetic Survey, and is no greater advance on Walker's telegraph method of 1847 than was that on the eye and ear method of previous centuries.

* Born 1805 in Massachusetts; graduated at Harvard 1825; founder of the observatory of the Philadelphia High School; appointed in the Naval Observatory at Washington in 1845.

Schott's initiation into the new ideas that were suggested in America covered not merely the application of the electric telegraph to longitude work, but equally so the application of Talcott's zenith telescope to the determination of latitudes, which rapidly replaced the prime vertical and other apparatus. In recent years the demonstration by S. C. Chandler of actual periodical variations in terrestrial latitudes and the corresponding periodical shift of the earth's polar axis was accepted by Schott with the liveliest interest, and in the light of this discovery he at once proceeded to review the observations of latitude made by numerous persons for use in the Coast Survey. He had previously given special attention and instructions as to the Coast Survey method of using the zenith telescope and had declined to order apparatus of the Repsold vertical circle type, having decided that the method of Capt. A. Talcott gave most reliable results.

CHARTOGRAPHY.

The methods of projecting or developing the surface of a spheroid on a flat surface of paper afford endless problems of importance to the geographer. Schott's decision was strongly and consistently in favor of the polyconic projection for many cases, and especially those in which large portions of the earth's surface are involved. Of course, a special system of projection must be adopted to suit the nature of a given problem, and he gave us a lucid, comprehensive summary of our knowledge on this subject, showing the relative values of the polyconic and other projections. The polyconic seems eminently adapted to some meteorological problems, and has lately been urged upon the attention of the international meteorological committee; but we still need a more appropriate projection—probably a modification of the polar projections.

The extensive memoir on projections by Craig and the comparisons by Schott, as well as his extensive tables for the use of the chartographer, constitute valuable additions to our knowledge of the subject.

MISCELLANEOUS OBSERVATIONS.

Several applications of mathematical methods to the needs of the work of the Survey led Mr. Schott to the consideration of special formulæ for interpolation. Thus we find a memoir by him, in 1860, on Cauchy's formula, and again one on the development of Bessel's functions, and another one on the solution of normal equations by indirect elimination.

A few personal observations of astronomical character were published by Schott, such as his observations of the variable star Algol, in 1856 and 1858, and his observations of solar spots, in 1860, 1861, 1862, enough to show that he was always willing to devote a few minutes of his precious time to assist others in gathering the facts needed in a new field of research.

TERRESTRIAL MAGNETISM.

Terrestrial magnetism occupied a large share of Mr. Schott's attention. His collections of original data on this subject are undoubtedly the most extensive of any that have been made relative to North America. They cover the widest range, both geographical and chronological; they were made the basis of the first detailed map of isogonic lines and of a study of the secular variation in magnetic declinations.

A historical review of the work of the Coast Survey in connection with terrestrial magnetism was published by Schott in the report of the Survey for 1888.

Our knowledge of terrestrial magnetism owes its present advanced condition to the universal interest in the magnetic needle, which has always been a puzzle to mariners, surveyors, and philosophers. Systematic observations of the needle were undertaken by all nations under the stimulus given by Alexander von Humboldt, Carl Friedrich Gauss, and General Sabine. They urged that Bache take up the subject, and the trustees of Girard College authorized him to build our first magnetic observatory in 1838. Observations at this observatory were made from 1840 to 1845, and in its connection a general magnetic survey of Pennsylvania was made, in 1840, by Bache. When he became the Superintendent of our Coast Survey, in 1843, he quickly saw that all this was but prepara-

tory to a great public work, and into this work Schott entered with delight. His own masters in Germany had imbued him with a sense of the importance of magnetics, and also with the pleasure of research in an unknown field. With Gauss and Weber as his great exemplars, Schott devoted all available time to magnetics. The accompanying bibliography shows the great work that he accomplished—an extensive collection of old American data; a complete new reduction of all the Girard College work; the construction of new apparatus and the determination of new values for dip, declination, and intensity at many American stations; an exhaustive study of the magnetic condition on board ships and the correction of the standard binnacle compass; the influence of the aurora; earth currents and magnetic storms and their relation to spots on the sun and the secular variation of the needle—until finally, in 1898, the council of the Academy of Sciences of France unanimously awarded to our colleague the gold medal established by Henry Wilde, and did not hesitate to say:

“The extensive work accomplished by Mr. Schott cannot be stated in a brief résumé. . . . The whole of this work furnishes one of the most important contributions in the history of terrestrial magnetism, and the committee is unanimous in awarding the Henry Wilde Prize to Charles A. Schott.”

The transmission of this medal to President McKinley and its presentation to Mr. Schott at the White House, February 4, 1899, formed a very pleasant episode. An extract from the President's remarks will always be worth reading:

“I congratulate you . . . that you have been chosen from all the world as the one most worthy to receive this great honor. It is especially pleasant in this age, when international relations are of high importance, to know that this fine prize, founded by an Englishman, has been awarded by Frenchmen and won by an American.”

In connection with the Wilde Prize, Dr. Henry S. Pritchett, who was at that time Superintendent of the Coast and Geodetic Survey, writes as follows:

“I knew Mr. Schott for a long time when I was an assistant to the Naval Observatory, but of course came to know him better when I went to the Coast Survey as Superintendent, in 1897. He was then the chief of the computing division, and it would be impossible to state too

highly his ability and zeal in this work. For years past he had been the strength of the Survey in its geodetic computations and operations. One incident which I remember with great pleasure was the conferring upon Mr. Schott, in 1899, of the prize awarded by the French Academy. He had been subjected to so many annoyances and difficulties that I asked President McKinley to confer this prize in person, and this was done at the White House, in the presence of a number of Mr. Schott's colleagues."

When the news of this honor reached Mannheim, that city realized that it also had a share in this distinction. The sweet character of this most modest and lovable of men, who was known to most of us only as the disciple of rigorous mathematics, is shown by his lasting affection for the home of his childhood and by his happiness at being once more brought into close connection with the scenes of his boyhood and the friends he had left just 50 years before.

The letter from the Mayor of the city of Mannheim with reference to the Wilde Prize is not in my hands, but I quote from a rough draft of Schott's reply:

"It has been one of my greatest pleasures to receive the sentiments expressed in your letter of December 16, referring to the occasion of the Wilde Prize lately awarded to me. What is most gratifying is the high appreciation on your part of any distinction conferred on one of the citizens of Mannheim, however long since and far away he may have wandered from his native town.

"I must recognize the fact that whatever success in after life I may have attained is in a great measure due to the solid foundation laid in my early education in the city of my birth and later on at Karlsruhe.

"After passing my State examination as civil engineer and anxious for active work, I left home in the disturbed year 1848, and was fortunate enough to find here a field open for my taste and ambition.

"I desire to thank you most sincerely for the transmission of the kind and appreciative sentiments sent me from my native town, which, I must confess, have once more strongly reminded me of the bonds which bind together my early and later life."

In Mr. Isaac Winston's contribution to our knowledge of Mr. Schott (*Science*, August 9, 1901) he mentions that the early recognition by Bache of Schott's ability, zeal, indefatigable industry, vast mental resources, caused his prompt assignment to the computing division and offered a wonderful opportunity to a man capable of distinguishing himself, and this

was realized to its fullest extent by Mr. Schott. He was placed in charge, in 1855, after jointly sharing its responsibilities with Mr. Hilgard, who was often absent in field work. From this time onward geodesy and magnetics claimed an equal share in the office work; meteorology and climatology as a part of terrestrial physics took up a greater part of his non-official time.

By such huge labors as these one must necessarily become a computing machine and an automaton; only the most rigid systematic economy of time and strength could enable one to endure this life-long habit of thought. Both quickness of action and economy of health were favored by his habit of standing at his work desk, thereby contributing to a state of health so perfect that no infirmity attacked him until the last few months of his life. He was always able to throw off the work and worries of office life and to find complete recreation in drawing and painting. Many specimens of the latter are still preserved.

CLIMATOLOGY.

Climatology afforded an attractive field for the gifted countryman of Humboldt, Kaemtz, Mahlmann, Lamont, Dove, and other students of physical geography. In addition to his extensive official works, Schott found time to publish a long series of volumes on the climate of America, beginning first with his temperature tables, 1876, and including the climate of the American polar region, meteorological observations in the Arctic Seas, similar observations in Arkansas, auroral observations at Lady Franklin Bay, magnetic observations at Point Barrow, and precipitation in the United States. Each of these volumes contains elaborate discussions of fundamental climatological data, and would give our colleague a place among the most prominent climatologists were he not already the most distinguished magnetist and geodesist of America.*

* As my four charts in Walker's "Statistical Atlas" of 1873 have by some been attributed to Schott and by others to Jackson and again to General Myer, it is proper to state that documents signed officially by high authorities sometimes originate with subordinates and are merely communicated over official signatures.

Unfortunately, the data in hand for climatological charts were in those days not sufficiently extensive to allow of reducing all the data to any given fundamental interval, as is now possible, owing to the accumulated 40 years of research by the United States Weather Bureau, therefore those pioneer charts are gradually being supplanted; but this does not destroy their character as having been an important step upward in this branch of science.

In 1862, in his reduction of the observations by McClintock, Schott gave us the first published table for converting the Smithsonian scale of ten arbitrary terms for the strength of the wind into the equivalent velocity in miles per hour. In the annual Coast Survey report for 1869 he was the first to invert the ordinary hypsometric formula, and thus make the barometric readings the basis of a computation of the average temperature of the air between any two stations. Thus he first demonstrated the truth of Ferrel's early assumption that there is only a very slight diurnal variation in the average temperature of the whole mass of air; the ordinary diurnal variation for any locality belongs to the ground and the air that is nearest thereto and not to the free air in the upper regions. A few years later this fact was also recognized in an extensive work by Ruhlmann (Leipsic, 1872), and ever since that date we have been justified in adopting a more uniform temperature throughout the day for the computation of altitudes by barometric readings. Of course, the same principle holds good when we consider the problem of reducing to sealevel any barometric observations made at a considerable height above the sea. This idea was embodied, in 1871, in the abolition of current temperatures when reducing stations from great altitudes to sealevel for the purpose of drawing isobars on our tri-daily maps for the morning, afternoon, and midnight. This idea was also embodied in a recommendation made in 1885 by Gen. William B. Hazen, as chief of the Weather Bureau, to the International Congress held in Paris, namely, that only fairly uniform temperatures, changing slowly from day to day and hour to hour, should be used in computing the reductions to sealevel. Subsequently Prof. William Ferrel indorsed the same method and it is now in almost universal use; so inti-

mately are geodesy and meteorology thus associated together.

Another point of contact relates to the adjustment of the horizontal levelings and vertical angles of geodetic triangles. In the case of vertical angles the measurement and computation of the atmospheric refraction is the fundamental question, and with this is associated the question of accurate hypsometry. On all these subjects, which may be called the mutual relations between the atmosphere and geodesy, many different memoirs, perhaps 30 in all, were written by Schott.

BASE-LINES AND METRIC STANDARDS.

The methods of measuring base-lines for the primary triangulation occupied our colleague's attention from an early date. New forms of compensated bars and new methods of transferring the measurement of one base-line to check measurements secured by measuring some distant base-line were always a delight to him. In general, however, it was absolutely necessary to secure consistency throughout the long years that elapsed between the first measurement of 1847 and the last adjustments of 1902. Of course, such consistency could only be secured by the retention of uniform methods of observation and computation throughout. Therefore the exigencies of the service may be said to have evolved the man, who was both conservative and progressive—a man who knew how and where and when to make changes that would not affect the final results disastrously.

One of the ultimate objects to be kept in mind in such extensive geodetic work is the determination of the true curvature of the earth for this part of the globe, and on this point Mr. Schott was very clear. There could be no gain in adopting a special curvature for the American continent until arcs of longitude as well as arcs of the meridian should have been measured.

Of course, the great geodetic operations of the United States must be combined with those of all other portions of the globe in order to improve our knowledge of the figure of the earth. But this cannot be done unless the base-measuring apparatus has been compared most carefully with the standards used by European geodesists. We therefore find a lucid memoir by

Schott on the relation of the metric standards of length in Europe and those used by the United States, the Coast and Geodetic Survey, and the United States Lake Survey.

GEODESY.

No better presentation of the breadth of Schott's comprehension of the province of our Survey can be desired than that given in his unpublished report of 1885 on "the Geodetic Survey of the United States, its objects and operations, considered from a theoretical and practical standpoint."

In the manuscript of this special report, communicated January 2, 1885, to J. E. Hilgard, as Superintendent of the Survey, we find a detailed statement of "the province and operations of a Geodetic Survey." Geodesy, astronomy, hypsometry, topography, gravitation are each properly evaluated and coördinated. The configuration of the true geoid as a slightly irregular modification of the fundamental spheroid is dwelt on as due to natural causes. The effect of the attraction of external mountains and internal excesses or deficits, on the equipotential surfaces under and over oceans and continents, the resultant variations both in the force of gravity and in the deflection of the plumb-line from the vertical, were clearly recognized; but the later ideas of isostasy and compensation as maintained by Dutton, in 1892, and demonstrated later by Hayford, were refinements for which practical geodesists were not yet prepared.

Little by little as Schott perceived the many new ideas that tended to dissipate his rapidly diminishing energies; as the founders dropped away and his earlier personal supporters found rest in the grave, he realized that he must relinquish every branch of work that did not bear directly on the computation of the results of the great triangulations that he wished to carry to their conclusion. Having divested himself of other details, he devoted his last years to the arrangement and, as it were, the codification of general results relative to two great geodetic arcs. The most delicate question, both in theory and practice, was the distribution of irregular densities within the earth and its effect upon deflections of the vertical and on the local forces of gravity. The first extensive discussions of

this subject had been by Archdeacon J. H. Pratt, of India. Isostasy had been defended strongly by C. E. Dutton, in 1892, and provisionally adopted by Helmert in his treatise on geodesy, in 1884. Since Schott's death, in 1901, isostasy, with definite ideas as to compensation, has been worked over thoroughly and with brilliant results by Hayford, in 1906, constituting, as Helmert once said, "a new epoch in geodesy." But during Schott's lifetime these seemed to him to be matters of subsidiary importance, and he was justified in omitting them from consideration until he had finished his first approximation to that figure that is appropriate to our knowledge of the American continent. In a similar way the study of the influence of the diurnal rotation of the earth on the east-west tidal strains as compared with the north-south strains is the important but minor matter investigated in the prize essay of 1912 by Prof. J. E. H. Love. The question whether the earth is a failing structure; the transmission and refraction of earthquake waves; the general character of variations of density, rigidity, and viscosity deep down within the solid earth, and other problems that are now of importance belonged to a future generation. Mr. Schott confined himself to the computation, in the customary manner, of the arcs already measured. The deflections were treated as though they were accidental errors. Hayford's method corrects the deflections (with a high degree of approximation), and hence nearly true curvatures are obtained. Schott had not found this method, and could not even attempt to correct for visible topography. Hayford had to devise new methods of computation to overcome the physical labor of doing what appeared to be an impossible undertaking with the means at his command.

A recent letter from Professor Hayford, who is now Director of the College of Engineering at Evanston, Illinois, says:

"Mr. Schott was remarkable for his extremely methodical ways, his German thoroughness, and his intellectual honesty. For fifty years he worked with clocklike precision of movement, not hastening in supposed emergencies nor slowing in dull times. His mental habits were like his physical habits—regular and methodical. He had definite plans as to what should be done and moved forward toward accomplishing those plans with patient persistence, passing many other more brilliant men in the march of progress by virtue of the cumulative effect of his

patient persistence and his careful methods. It is my belief that next to F. R. Hassler he left more influence for good on the Coast and Geodetic Survey than any other man who has ever been connected with it."

The tangencies of continental outlines and of mountain ranges to the polar circles were emphasized by Robert Dale Owen, geologist of Kentucky. The fact that all these lines run tangent to the two polar circles shows that general faults have occurred during certain geological ages only when the strains in the earth's crust have been a maximum, and such can occur only when the sun and moon act together at apogee and perigee, just as with the ocean tides. The strains are due essentially to the push and pull of the ellipsoidal or equatorial bulge and have some hidden relation to terrestrial magnetism. The innumerable cracks and faults throughout the earth's crust show that although each bit of rock is rigid, yet the mass as a whole may be treated as a viscous globe, in which each uncracked piece of rock is as it were an independent molecule. A great fault or crack is located along the great circle of the Rocky Mountains, the Andes, Japan, the mountains of central Africa, and these constitute but a belt of weakness in the whole outer crust, extending entirely around the globe, giving us an aqueous and a continental hemisphere. The province of geodesy is to determine, first, approximately and then more exactly the shape of this resulting irregular globe. Every thought in Schott's life-work had this object in view, and it was fortunate that his health and strength were spared to give us a first approximation to the shape of the North American continent as the logical conclusion of the totality of the geodetic work that had been conducted for fifty years by the whole Survey under his general guidance and detailed supervision.

The most remarkable of modern philosophers and the most modest—Sir Isaac Newton—knew that the earth must be a spheroid of revolution. Its dimensions were deduced very closely by Bessel in 1840, and Clarke in 1865 and 1880, based on measures made in the meridian, in Europe, Africa, India, and equatorial America. Pierce added to the conscious dignity of our Survey by enforcing its broad duty as both a Coast and a Geodetic Survey. Under his superintendency an arc of the

parallel from New York to San Francisco was authorized. This was additional to the oblique arc from Maine to Florida that was begun in the early days of the Survey, to which a meridional arc from Texas to Dakota is now added. Of all these far-seeing men it was Schott alone who was spared to see the completion of the longitudinal and the oblique arcs—arcs of unsurpassed extent and accuracy. A thousand men had lived and worked, grown old and died, and still the work had gone on. The Mexican war, the Civil war, and the Spanish war had rolled over us like waves in the progress of the nation. Inventions and ideas by the thousand had contributed to the accomplishment of the work of the Survey, and still it went on; still Schott labored persistently in his little office-room, devotedly hoping and praying that he might live until the first results were attained as to the curvature of the globe. All had started out together, in 1843-1848, as geodetic pioneers in these new lands; the country had spread from the Atlantic to the Pacific; it had taken in Texas on the south and Alaska on the north; it had assumed control from Porto Rico to the Philippines. Schott could only hope to determine as a first step whether the curvature of America agreed with that of Europe, and well pleased were all to learn that his computations for our continent fell midway between the results of Bessel and Clarke for Europe.

Such a calculation as this, enlarging and fixing our ideas of the powerful action of gravity over the whole globe, may well have called forth emotions in his mind like those experienced by Sir Isaac Newton when he demonstrated that universal gravitation kept the earth and the moon in their proper places with respect to the sun. Schott's name is attached to these two great works on the longitudinal and the oblique arcs, but he added to his fame and reputation when he recognized a fact that is implied in his statement, "We have accomplished the work; but not I alone." It is thus that he stands at the summit of the pyramid that the whole Survey had erected, when he emphasizes the unity of all their labors. It was the culminating contribution by America to the sum total of human knowledge regarding the exact shape of this globe of earth as the home of mankind. We place Schott's name beside those

of Benjamin Franklin, Alexander Dallas Bache, Joseph Henry, and all others who have relinquished their own personal inclinations in order to carry out, unselfish to the end, the great works that each felt called on to do. Many a man seeks for that which gives personal ease and pleasure, but few seek for the highest usefulness that they are capable of.

In a letter extending the sympathy of the Prussian Geodetic Institute to the Coast Survey on the loss which the latter had sustained in the death of Schott, the eminent Director, Dr. George Helmert, thus refers to Schott's activity:

"I am pleased to think that it was a German who developed for so many years such a wonderful activity in the Survey, and thus Mr. Schott did not only render great services to science by his successful work, but contributed to the esteem which two great nations have for each other."

The completion of the two arcs already mentioned marks an epoch in the geodesy of the world. Such gigantic works require very fortunate and rare combinations of national funds, stable governments, learned theories, convenient opportunities, and well-trained experts. The administration of F. R. Hassler, 1806 to 1843, was necessarily occupied with details of small extent and daily importance, nor was the wealth of the young nation at that time favorable to such a great work. The administration of the gifted Bache, 1843 to 1871, was crowded with a multitude of duties—novelties of organization and momentous national difficulties. The later administrations of Patterson, Pierce, Hilgard, Mendenhall, Pritchett, and the present long administration of Tittmann have enabled Schott and his successor, Hayford, to accomplish great works, for which the Survey now becomes famous in the field of scientific research.

Our globe incites to innumerable problems, and every advance in our knowledge suggests still others. Perhaps those that press most earnestly for speedy solution relate to earthquake phenomena and the internal structure of the globe. Both geodesy and meteorology require so-called reductions to sea-level; the former would reduce pendulum observations of gravity; the latter would reduce barometric observations of

air pressure, and each requires some knowledge of the other. The fact that Hayford has shown that the observed deflections from the vertical, and that Bowie has shown that the observed variations in the intensity of gravity, are both satisfactorily explained by a proper consideration of isostasy and compensation, justifies our belief that future researches will give us correct ideas on the questions discussed by A. E. H. Love: *Some Problems of Geodynamics* (Cambridge, 1911). In this connection it would seem proper and necessary for the Survey to enter also into the study of seismology, which is now prosecuted so vigorously in Europe and promises to give us definite knowledge with regard to the interior of the globe.

The progress in terrestrial magnetism made by Bauer leads us to hope that another step may be made when we understand the influence of earthquake shocks in rearranging the superpermanent magnetic conditions of rocky strata. Some ideas on this subject were presented to the National Academy in 1887, which were subsequently published in 1889, at pages 8-17, of my "Preparatory Studies," and may possibly be worth considering. It was Francis Bacon, of 1605, who said: "Knowledges are as pyramids whereof history is the basis; so of natural philosophy the basis is natural history; the stage next this basis is physic; the stage next the vertical point is metaphysic." Nowadays we omit the metaphysics, but are busy enough with natural philosophy and physics.

The few words that we have given relative to history and physics must now be concluded with a tribute of affection and respect as to Schott's personal influence. From 1860 to 1867 I was only an humble aid in the Coast Survey, but I had known him by correspondence for a few years. My first personal interview and conversation was on the 3d of May, 1867, and I shall never forget the smile of genial sympathy as he discussed with me the need of greater accuracy in every line of work bearing on astronomy and geodesy; the need of divesting ourselves of every trace of injustice; the need of frankness and an honest recognition of assumptions that secretly beset every investigator. He entered lovingly into ideas that I brought back from Poulkova and into plans of astronomical work. He was the most helpful of friends, equally ready to give advice

or to do helpful work. His long experience had inculcated the habit of patience in dealing with men. He knew how difficult it is for one man to see into a problem with the mental eyes of another. I could never think of him as arbitrary or as saying anything that injured the progress of any worthy individual. His wide experience and greater knowledge seemed always to harmonize with and widen the knowledge of others. His judgment and my theories sometimes coincided, and there was an affectionate aspect to our friendship, a mutual appreciation, a respectful confidence, such as must have been deeply realized by others as well as myself.

Mr. Vinal, who came into the service 10 years after myself, was impressed like myself. He writes:

"Mr. Schott was a man of earnest purpose, having at all times the best interests of the service at heart, systematic and thorough in all that he undertook. He accomplished a great work, as evidenced by his numerous reports and publications. All that come after him can only follow where he led."

A few paragraphs from Prof. T. C. Mendenhall, who was Superintendent during the years 1889-1894, may properly conclude these lines:

"My acquaintance with Schott began a good many years before it was my pleasure to be officially associated with him in the Coast and Geodetic Survey.

"During that association, lasting more than five years, my admiration for him increased, and there was added to it a genuine affection growing out of his many charming personal qualities which were revealed, it sometimes seemed, almost reluctantly. In the hundred years of its existence the Coast Survey has enjoyed the services of many devoted and unselfish men; but few others, if any, have equalled Schott in the faithful and conscientious devotion of his best abilities to the discharge of his duties. The best interests of the Survey and its work invariably received his first consideration.

"The computing division, over which he presided, was as important to the whole organization as is the heart to that of a living man, though like that its work seemed to many almost painfully monotonous. His peculiar fitness for it was shown by the fact that to him it was never irksome. On the contrary, I am sure he found delight in the laborious calculations in which he and his staff were continually engaged, for he knew that here was the crucible in which all of the various operations of the corps were at last tried out. He was quick to

recognize the excellence of a field officer's work when found satisfactory, after his rigid tests had been applied, and although by nature reserved in disposition and never lavish in praise, he was always glad to call generous attention to such work. On innumerable occasions he brought to me a few sheets of final computations, proving the high precision and satisfactory character of a bit of field work, and I do not believe the observer himself could have found more pleasure in the results. In time I came to regard him as an excellent judge of the abilities and merits of men, for his conclusions were founded on tests of actual performance, uninfluenced by personal preference or prejudice.

"His scientific work was characterized by a painstaking thoroughness which marked everything he did. Although along certain lines, notably that of terrestrial magnetism, he was recognized as one of the world's first authorities, yet I do not believe that his scientific investigations have yet received the general recognition and commendation to which they are entitled in virtue of their importance, extent, and high character. Although a man of no uncertain mind regarding scientific questions upon which he believed himself competent to speak, Schott was excessively modest and often declined to express views to which the scientific world would have listened with both pleasure and profit. Indeed, it was difficult to induce him to read a paper before small scientific societies, of which he was himself a member. Through long, industrious years his work went on quietly, much of it attracting little attention at the time. Few men have done so much with so little attending noise, and in this respect, as well as in many others, the example of his life may wisely be studied by those who have survived him."

In conclusion one may be allowed to express regret that those distinguished chiefs of the Coast Survey—A. D. Bache, Benjamin Pierce, Carlisle Patterson, J. E. Hilgard—with whom Schott had served for so many years, cannot testify to us to-day as to their appreciation of his early services. I have quoted only from their successors—Mendenhall, Pritchett, and Tittmann—as to his later work. A few words from many of his old associates would have most gracefully concluded our brief review; but they, like him, repose under the green turf, in the silence of death. Only the organization of the Survey still stands—a permanent living monument to the foresight, energy, and ability of its founders. Through our Coast and Geodetic Survey new chapters have been added to the history of geodesy. It has been the foster-parent of new branches of exact science and has earned an imperishable crown of gratitude from all students of terrestrial physics.

A CATALOGUE OF THE WORKS (ABRIDGED TITLES) OF
CHARLES ANTHONY SCHOTT,

ASSISTANT, U. S. COAST AND GEODETIC SURVEY, 1848-1901.

Compiled by Ralph M. Brown, October, 1908.

ABBREVIATIONS.

app.	Appendix.	Rep.	Report.
Bull.	Bulletin.	Sep. publ.	Separate Publication.
pp.	Pages.	Spec. publ.	Special Publication.
pt.	Part.		
Amer. Assoc. Adv. Sci.	American Association for the Advancement of Science.		
Amer. Journ. Sci.	American Journal of Science.		
Trans. Amer. Soc. Civ. Eng.	Transactions American Society of Civil Engineers.		
Astron. Journ.	Astronomical Journal.		
Astron. Jahresber.	Astronomischer Jahresbericht.		
Nat. Acad. Sci.	National Academy of Sciences.		
Nat. Geogr. Mag.	National Geographic Magazine.		
Rep. U. S. Coast Geod. Surv.	Report of the U. S. Coast and Geodetic Survey.		
Sci. Amer. Suppl.	Scientific American Supplement.		
Smiths. Contr. Knowl.	Smithsonian Contributions to Knowledge.		
Smiths. Misc. Coll.	Smithsonian Miscellaneous Collections.		
Terr. Magn.	Terrestrial Magnetism and Atmospheric Electricity.		
Bull. Phil. Soc. Wash.	Bulletin of the Philosophical Society of Washington.		
Tables for projecting maps, with notes on map projections. (With E. B. Hunt.) Rep. U. S. Coast Geod. Surv., 1853, app. 39, pp. 96-163.			
On the currents of Nantucket shoals. Rep. U. S. Coast Geod. Surv., 1854, app. 48, pp. 161-166.			
Currents in Muskeget channel and off the northeast coast of Martha's Vineyard. Rep. U. S. Coast Geod. Surv., 1854, app. 49, pp. 166-168.			
Tidal currents of Long Island sound and approaches. Rep. U. S. Coast Geod. Surv., 1854, app. 50, pp. 168-179.			
Adjustment of horizontal angles of a triangulation. Rep. U. S. Coast Geod. Surv., 1854, app. 33S, pp. 70-95.			
Discussion of the secular variation in the magnetic declination on the Atlantic and part of the Gulf coast of the United States. (Ed. I.) Rep. U. S. Coast Geod. Surv., 1855, app. 48, pp. 306-337.			

- Results of observations for magnetic declination, dip, and horizontal intensity. Rep. U. S. Coast Geod. Surv., 1855, app. 49, pp. 337.
- Solution of normal equations by indirect elimination. Rep. U. S. Coast Geod. Surv., 1855, app. 40, pp. 255-264.
- Discussion of the secular variation in the magnetic declination on the Atlantic and Gulf coasts of the United States, from observations in the 17th, 18th, and 19th centuries. (Abstract from a report to the superintendent of the Coast Survey, dated July 6, 1855. Rep. U. S. Coast Surv., 1855, app. 48, and communicated by authority of the Treasury Department.) Proc. Amer. Assoc. Adv. Sci., vol. 9, Aug., 1855, pp. 160-175. Suppl. Amer. Assoc. Adv. Sci., vol. 10, Aug., 1856, pp. 173-177.
- Contribution to our knowledge of the climate of the American polar regions, with an accompanying illustration. In E. K. Kane, Arctic explorations, vol. 2, pp. 426-428. Philadelphia, 1856.
- Comparison of star-places given in Rümker's and the Twelve-year catalogues. Rep. U. S. Coast Geod. Surv., 1855, app. 45, pp. 278-286, and Astron. Journ., vol. iv, 1856, pp. 113-120.
- Magnetic observations made at stations in Delaware, Maryland, and Virginia. Rep. U. S. Coast Geod. Surv., 1856, app. 29, pp. 226-227.
- Results of observations for magnetic declination, dip, and horizontal intensity at stations in Delaware, Maryland, and Virginia. Rep. U. S. Coast Geod. Surv., 1856, app. 30, p. 227.
- An attempt to determine the secular change of the magnetic declination on the western coast of the United States. Rep. U. S. Coast Geod. Surv., 1856, app. 31, pp. 228-235.
- Discussion of the secular variation of the magnetic inclination in the northeastern states. Rep. U. S. Coast Geod. Surv., 1856, app. 32, pp. 235-245.
- An attempt to determine the secular variation of the magnetic inclination on the western coast of the United States. Rep. U. S. Coast Geod. Surv., 1856, app. 33, pp. 246-249.
- Discussion of the secular variation of the magnetic inclination in the northeastern states. Proc. Amer. Assoc. Adv. Sci., vol. 10, Aug., 1856, pp. 177-187. Rep. U. S. Coast Geod. Surv., 1856, app. 32.
- Determination of the probable error of an observation from the differences of the observations from their arithmetical mean. Rep. U. S. Coast Geod. Surv., 1856, app. 59, pp. 307-308.
- Contribution to our knowledge of the climate of the American polar regions, with an accompanying illustration. In E. K. Kane, Arctic explorations, vol. 2, pp. 426-428. Philadelphia, 1856.
- Notice of the determination of the longitude of Fernandina, Amelia island, Florida, by means of chronometer exchanges from Savannah, Georgia. (With A. D. Bache.) Proc. Amer. Assoc. Adv. Sci., 1857, pp. 166-175; Canadian Journ., 1858, vol. 3, pp. 71-73. Also published as Rep. U. S. Coast Geod. Surv., 1857, app. 30, pp. 314-324.
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- nomical latitude by means of the zenith telescope. Rep. U. S. Coast Geod. Surv., 1857, app. 31, pp. 324-334.
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- Observations of the algol-minimum of 4th December, 1856, at Washington city. Astron. Journ., vol. 5, Dec. 11, 1857, p. 93.
- Observations of the algol-minima of 21st of January and 5th of March, 1858 [at Washington, D. C.]. Astron. Journ., vol. 5, April 2, 1858, p. 128.
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- Rediscussion and development of an intermediate period in the secular change of the magnetic declination at Hatboro, Pennsylvania. Rep. U. S. Coast Geod. Surv., 1858, app. 25, pp. 192-195.
- Report on the progress made in discussing the secular variation of magnetic declination and dip, at Washington, D. C. Rep. U. S. Coast Geod. Surv., 1858, app. 26, pp. 195-197.
- Abstract of the principal results of the observations for temperature, at Van Rensselaer harbor, North Greenland, made by the second Grinnell expedition, under the command of Dr. E. K. Kane, U. S. N., during 1853-1854-1855. Presented by Prof. A. D. Bache, from a reduction and discussion by Chas. A. Schott, assistant, Coast Survey. Proc. Amer. Assoc. Adv. Sci., vol. 13, 1859, pp. 264-270. For complete paper see Smiths. Contr. Knowl., vol. 11, art. 5, pt. 1, pp. 1-50.
- Abstract of the principal results of the discussion of observations for atmospheric pressure at Van Rensselaer harbor, North Greenland, made by the second Grinnell expedition under the command of Dr. E. K. Kane, U. S. N., during 1853-'54 and '55. Presented by Prof. A. D. Bache, from reduction and discussion by Chas. A. Schott. Proc. Amer. Assoc. Adv. Sci., vol. 13, 1859, pp. 270-276. For complete paper, see Smiths. Contr. Knowl., vol. 11, art. 5, pt. 3, pp. 81-111.
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Mr. Fisher Longstrech

NATIONAL ACADEMY OF SCIENCES
BIOGRAPHICAL MEMOIRS
PART OF VOLUME VIII

BIOGRAPHICAL MEMOIR

OF

MIERS FISHER LONGSTRETH

1819-1891

BY

REBECCA C. LONGSTRETH

PRESENTED TO THE ACADEMY AT THE ANNUAL MEETING, 1914

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MIERS FISHER LONGSTRETH.

MIERS FISHER LONGSTRETH, only son of Samuel and Sarah Redwood Longstreth, was born in Philadelphia March 15, 1819. His maternal grandfather, Miers Fisher, was a distinguished Quaker lawyer of Revolutionary times. Deprived of both parents at the early age of eight years, he with his sisters made his home with near relatives. In the spring of 1828 he entered Clermont Academy, near Philadelphia, remaining until 1833, when he entered the Classical Academy of M. L. Hurlburt, and was advancing rapidly in Spanish, French, and especially Latin, when he left school to enter business. He was placed in a hardware store, where he remained for many years, becoming a member of the firm in 1840.

Throughout his business career he ever pursued his studies, and, having a strong desire for knowledge, as early as 1837 attended evening lectures on anatomy, and during one winter took a course in the College of Pharmacy of the University of Pennsylvania.

In 1843 he married Mary Tyson Clapp. Adjoining their home the Friends' Central School was established. The new building had an astronomical observatory, the use of which was offered to Dr. Longstreth. His guardian provided him with funds to purchase a telescope (made after Merz and Mahler pattern, 5-inch object glass), he already owned a transit instrument and a clock had been presented.

It was here that he made the discovery of the inaccuracies of the tabular longitude of the moon. The result of his labors is best given in a paper read by Professor Pierce at the American Association, Albany, 1851, entitled "An Account of Longstreth's Lunar Formula."

LONGSTRETH'S LUNAR FORMULA.*

Professor Pierce stated that the title of the paper was probably sufficient to tell what he meant to say. But he wished it

* From *Annual of Scientific Discovery*, Boston, 1852, pp. 380-381.

distinctly understood that he only intended to give an account of a discovery by a man who was as remarkable for his extreme modesty as for the eminence of the position which he occupied among the scientific benefactors of the age. The very modest manner in which Mr. Longstreth had announced his discovery was worthy of remark. He would read from the preface to the published tables all that Mr. Longstreth had himself said in relation to this great discovery. It was as follows: "The coefficients deduced from theory by Damoiseau, Plana, Pontecoulant, and those deduced from observation by Burckhardt (though differing considerably), give the moon's place with nearly the same accuracy."

Previous to this tabular formula prepared by Mr. Longstreth there was no method of testing the theory. All will remember the celebrated dispute between Newton and Flamsteed as to the investigation of the formulas for the longitude of the moon. Longstreth had obtained results which involved the true theory of variations of the moon's longitude. The results of observations, now that we had a tabular formula to compare them with, when spread over sufficient ground, would be sure to be confirmed by theory subsequently. Professor Pierce exhibited the tables themselves, showing where Damoiseau and Plana agreed and where they began to differ, and stating that Professor Airy, of England, had compared the results obtained by Longstreth.

By means of Longstreth's formula we are sent back to the theories of Damoiseau and Laplace. The difference had been ascertained to be greater between Plana and Laplace than between Laplace and Damoiseau. We are therefore traveling backward to the theory propounded by Laplace, while the supposed advances made by the later physical astronomers are assuming their true position.

Mr. Longstreth's observations are now to be used in the American Nautical Almanac. This alone renders that work of the utmost importance to navigators of every nation, as well as of this country.

In 1853 he withdrew from mercantile life and entered the Medical Department of the University of Pennsylvania, graduating in 1856. Dr. Longstreth continued to reside in Phila-

delphia for twelve years after his marriage, but, in 1855, he, with his family, moved to Sharon Hill, near Darby, Delaware County, Pennsylvania, which was his home during the remainder of his life. This afforded him an opportunity for the cultivation of the various branches of natural history in which he took especial pleasure. Here Dr. Longstreth quietly practiced his profession, but not to the extent which he might have done had he sought practice. The neighbors, far and near, rich and poor, knew they had a kind, sympathetic friend standing ready and willing to meet every need within his power.

His great interest in education was shown by his unfailing labor in Swarthmore College, established for the young men and women of the Society of Friends. He was a member of the Board of Trustees for nearly twenty years and served the college in many ways, one of the most important of which was by his wise and valuable counsel.

After laying aside his more active duties, true to the instincts of his earlier life, he continued his love of books and study. He took a great interest in Hebrew, Arabic, and Syriac, that he might become more familiar with the Scriptures, and was as enthusiastic a student in a class formed for the study of the former as those of one-half his years.

Continuing his interest in astronomy, he always referred with much pleasure to his observation, in 1869, near Bristol, Tennessee, of the total eclipse of the sun, and he had a very good opportunity to observe the Transit of Venus December 6, 1882, at his private observatory at Sharon Hill. In 1848 he was elected a member of the American Philosophical Society, at Philadelphia.

Dr. Longstreth was one of the founders of the National Academy of Sciences, in 1863. After some years he resigned from active membership and was placed on the list of honorary members.

During his last illness, which confined him to bed for many months, his cheerful and unselfish spirit was evinced even in the midst of severe suffering. Retaining all of his faculties until the close, he peacefully entered eternal life December 27, 1891.

Throughout his life he was a consistent and devoted member

of the religious Society of Friends, bearing his share of the responsibilities of its work. Always modest and unassuming, he lived a peaceful, quiet life, and his true worth became known to comparatively few. But those who knew him best esteemed him most, and he has left with them those precious memories of an unselfish life, devoted to increasing the happiness of all who came within the sphere of his influence.



Henry Morton.

NATIONAL ACADEMY OF SCIENCES
BIOGRAPHICAL MEMOIRS
PART OF VOLUME VIII

BIOGRAPHICAL MEMOIR

OF

HENRY MORTON

1836-1902

BY

EDWARD L. NICHOLS

PRESENTED TO THE ACADEMY AT THE ANNUAL MEETING, 1914

CITY OF WASHINGTON
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February, 1915

HENRY MORTON.

HENRY MORTON was born in the City of New York on the 11th day of December, 1836. He studied at the University of Pennsylvania, from which institution he was graduated (1857) in his twenty-first year.

It does not appear that science appealed strongly to Morton during his student days. Indeed, his interests chanced to be drawn in quite another direction. During his junior year a plaster cast of the Rosetta stone, of which at that time no translation had been completed, was presented to the Philomathean Society of the University.

Morton, in collaboration with other members of the society, undertook to make a translation; and, although he was without previous experience in such work, he made a complete rendering of the hieroglyphic text before the close of his senior year.

Not content with this achievement, exceptional, if not indeed unparalleled, in the annals of undergraduate activities in America, he illuminated his manuscript with appropriate and striking designs. These were much admired, and regret was expressed that it would not be possible, on account of the cost, to publish them in the original colors. Thereupon, although without any training as an engraver, he made with his own hands drawings on stone for the entire work, and an edition was printed and speedily sold.

Art, with which he was thus brought in touch in the illustration and illumination of his manuscript, and archeology, which became a real and live thing to him as he sought the interpretation of the hieroglyphics of the Rosetta stone, were to be subjects of intense and life-long interest; but neither drew Morton from the beaten track in his choice of a career. On the contrary, he began the study of law after graduation, and the introduction to what was to become his life work came quite fortuitously two years later.

His father, the Rev. Henry J. Morton, who was rector of St. James Church in Philadelphia, was also a member of the

governing board of the Episcopal Academy of that city, the school in which Henry Morton had been prepared for college.

In this school, in which there was no regular provision for the teaching of the physical sciences, Morton volunteered to give a series of lectures on chemistry and physics. The success of these lectures, which was immediate and striking, seems to have determined his career. So entertaining were they, and the illustrations so brilliant, that the little lecture-room was soon overcrowded, and a larger one was built to accommodate the audiences that gathered to hear him.

Other lecture engagements followed and Morton became, in a way, a local celebrity. In 1863 he was appointed to the professorship of chemistry in the Philadelphia Dental College; in 1864 he became the secretary of the Franklin Institute, and in 1867 the editor of the old and established journal of that society. In 1868 he accepted a professorship in chemistry at the University of Pennsylvania. In 1870, at the age of thirty-four, he was offered the first presidency of the Stevens Institute of Technology, which institution had been provided for by the will of Edwin A. Stevens, of Hoboken, who had died in 1868. This position Henry Morton held until his death, in 1902.

The period (1864-1870) during which he was secretary of the Franklin Institute was one of great and varied activity. To arouse public interest in the society, which had fallen into a comatose state, a series of public lectures was planned to be given by Morton in the Academy of Music. He undertook the precarious task with enthusiasm and met with immediate and remarkable success.

To adapt scientific demonstrations to the stage of a great theater and make them effective and entertaining, as well as accurate and instructive, demands other qualities besides that of knowledge of the subject and ordinary powers of exposition, but Morton was equal to the occasion. He developed the gifts of a skilled stage wright and artist in addition to those of a man of science. He selected his experiments with a view to the possibility of making them visible and effective to so large an audience and produced them with scenic effects calculated to appeal to the imagination.

The enthusiasm of the public which thronged the theater on these occasions was due in no small measure to the manner in which his effects were staged. To exhibit the phenomenon of the combustion of iron in oxygen, for example, a sword was burned by the lecturer standing at a high altar in the middle of the stage, with an appropriate background of storm clouds and high mountains.

In an address delivered at the time of the presentation of Morton's portrait to the Stevens Institute, Dr. Coleman Sellers gave the following interesting and graphic account of these public lectures. The passage is taken from the Morton Memorial Volume published by the Alumni Association of the Institute in 1905, a work to which the present writer is indebted for many facts concerning the subject of this biographical notice.

"At one of the first meetings of the managers of the Franklin Institute after Mr. Morton's appointment, it was suggested that an excellent means of interesting the public at large in the objects of the Institute would be a course of scientific lectures, delivered in some large hall.

"One of the managers was even so bold as to suggest the Opera House or Academy of Music, one of the largest auditoriums in the country, seating more than 3,500 persons. Others considered this too venturesome, but it was finally decided to leave this to Mr. Morton's decision.

"Deputed to communicate with Mr. Morton on this subject, I well remember the characteristic courage and enthusiasm with which he at once seized on the idea of making the so-far unparalleled experiment of devising and executing illustrations on such a scale as should render them impressive on so large a stage and to so vast an audience.

"All who came in contact with him were inspired with his confidence and enthusiasm (myself among the number), and the preparations were commenced at once.

"Some notices of these got abroad, and long before the date assigned for the lecture every seat in the house was sold; and so pressing was the demand that the Academy was engaged for another evening, a few days later, and, before the night of the first delivery arrived, every seat had been again sold for the repetition.

"There are occasions, even in the life of a scientific professor, which call for no small stock of moral courage, and the evening in which Mr. Morton for the first time walked forward upon a public stage in the face of an audience which crowded every seat and every inch of standing-room, with the consciousness that he was committed to the absolute necessity of a success by the arrangements for the repetition, was one of them.

"I was with him at the time, having undertaken the office of manager, to direct and superintend the work of his assistants behind the scenes; and I have not forgotten what were my own feelings.

"But when the curtain rose, he stepped forward with easy grace amid the enthusiastic applause which greeted his appearance, and began his lecture as calmly and collectedly as if he had done the same thing fifty times before.

"He told me afterward that he was so anxious about the success of his experiments that he had no room in his mind for personal embarrassment, or the nervous agitation often caused by facing a great audience.

"I need hardly say that the lecture throughout was a success. The clearness of the explanations and the novelty and beauty of the experiments held the audience in close attention for nearly two hours, and when Mr. Morton made his exit from the stage, amid applause even heartier than that which welcomed him, he carried with him a reputation as a scientific lecturer which I believe has never been equalled.

"During the following years similar lectures on related subjects were given by Mr. Morton in the same place. Some of their titles were the following: Reflection, Refraction, Sunlight, Moonlight, Eclipses, Fluorescence, and so on.

"In these lectures Mr. Morton used not only numberless new devices for the production of striking illustrations of scientific phenomena, but also brought into play appliances of the stage, such as shifting scenery to aid in color effects, stage traps to bring apparatus into position when wanted, and endless other applications."*

In such work the "art of projection" is a prime factor, and the implements of this art were then but imperfectly developed. To this subject Morton gave much attention. In the *Journal of the Franklin Institute* he published a series of useful papers† dealing with such details as condensers and objectives, the generation of oxygen and hydrogen, and the best arrangement for vertical projection. The final result was the production of a lantern, which, for general scientific purposes, was far superior to anything then existing, and which was only superseded when the introduction of the right-angled arc lamp, a quarter of a century later, rendered a somewhat more compact form practicable.

During these busy years Morton worked for the rehabilitation of the Franklin Institute and, as its editor and frequent con-

* Morton Memorial Volume, Hoboken, N. J., 1905, p. 170.

† *Journal of the Franklin Institute*, vols. 53, 54, 55, 62, 63, etc.

tributor, for the reestablishment upon a sound basis of the Journal of the Franklin Institute. In addition to these tasks, in both of which he was eminently successful, he fulfilled his duties as professor of chemistry.

In 1869 he led a party of Philadelphia observers to Iowa to take photographs of the solar eclipse of August of that year. The success of this expedition was largely due to his genius as an organizer, and although not an astronomer by training he was able to contribute to the discussion of the results, particularly in the matter of distinguishing between appearances due to the photographic process and the solar phenomena which it was the purpose of the investigation to record.

Knowledge of the properties and behavior of photographic plates was at that time even more imperfect than at the present day, and the results of such processes as halation, reversal, and the like were more frequently misleading. Morton indeed is said to have been the first to establish the spurious character of certain features already frequently observed in photographs of eclipses and hitherto misinterpreted.

When Morton went to Hoboken and assumed the directorship of the Stevens Institute of Technology, he gave himself to the organization and development of the newly opened school with all his wonted energy and intelligence. The technical school as we now know it did not exist. To the academic mind, at least, engineering at that time meant civil engineering, with mining as one of its branches. Mechanical engineering as a learned profession had scarcely begun to receive recognition.

College training, especially planned for the education of builders of machinery, with shop work and laboratory practice as important features in its curriculum, was something the usefulness of which was yet to be proven. Electrical engineering, before the day of dynamos, motors, electric light, electric traction, had not even a name. Thirteen years were still to elapse before electricians were strong enough to declare themselves and to start the Institute of Electrical Engineers.

In this pioneer work of building up a special school for professions just struggling into organized existence, Morton as head of the Stevens Institute took an important part. For

thirty years, during which invention and all that pertains to the mechanical aspects of civilization were growing at a pace unknown in the history of the world, it was his task to keep himself and his school abreast with the onward movement of the times. That matters administrative, technical, and industrial should utterly submerge him was only to be expected; it might almost be said to be inevitable. Then, too, the great city across the river demanded him. It called upon him for service in a thousand ways. On account of his keen mind and his unusual powers of exposition, he was much sought after as a witness in patent litigation involving scientific principles, and he soon became the foremost patent expert of his day.

He did not lose interest in pure science, however, nor immediately cease to contribute to its advancement. In 1871 appeared the first of a notable series of papers on fluorescence,* in the course of which the absorption bands and fluorescence bands in the spectra of anthracene and crysogene were described and the changes which occurred in solutions of these substances were noted. The remarkable character of the fluorescence spectra of the uranyl salts was also made a subject of investigation, and Morton was probably the first to recognize the displacement of the absorption bands of uranyl acetate when that substance passed from the solid into the solvent state.

Although as time went on his published work, for he was ever a prolific writer, took more and more the form of remarkably lucid and accurate accounts of the investigations of others, and although in later years his many-sidedness led him into fields of thought as remote from chemistry as were in an earlier day the egyptological investigations of Thomas Young from his proper field of optics, we may yet find continued evidence of his lively concern for everything of a scientific nature and of his being an inspirer of good work on the part of his faculty and students. Some of the very earliest work in the study of the wave forms of alternating electric currents, for example, was done at his suggestion and with his collaboration by the late B. F. Thomas,* afterwards Professor of Physics in

* Journal of the Franklin Institute, vols. 62, 63, 64; Chemical News, vol. 27.

* B. F. Thomas: Trans. Amer. Inst. Elec. Eng., vol. IX, 1902, p. 265.

Ohio State University, who was at the time a student at the Stevens Institute.

The varied intellectual and æsthetic gifts which in undergraduate days had led to the translation of the Rosetta stone, and to the decoration and illustration of the volume in which the results of that attempt were published, manifested themselves again in later years.

To an intimate circle Henry Morton was known not merely as the head of Stevens Institute, an engineer, and a writer on technical subjects; nor merely as a generous donor who from time to time turned over to the Institute a considerable portion of his large earnings for the endowment of chairs and the erection of buildings. They knew him as a student of biblical criticism, an archeologist, a writer of verse, and as an artist and a lover of art. Indeed, it was maintained by competent judges in these widely different fields that had he chosen to devote himself to any one of them he would have taken high rank. -

In the words of one of his intimate friends, Thomas A. Janvier, his personality has been vividly characterized in the following passages:*

"In my twenty years' friendship with Dr. Morton I saw many of his many sides, and in all of them there were both edification and charm. But oftenest—because of his keenly sympathetic intuitions which made him adapt himself to the mental capacities, and even to the mental incapacities, of his friends—our talks were of literary matters, and of his own lighter activities (as they were by contrast with the varied very serious activities of his highly useful life) in literary ways.

"His habit, in common with many hard thinkers, was to seek mental relaxation in story-reading: a little laughing at his own liking for vivid fiction; but rarely failing to make his excursions into romance of value to others by a running fire of commentary in which his wit and his critical acuteness had full play. As a critic he was admirable; precisely because he had high literary standards, and because he lived up to those standards in his own literary work. In literature, as in science, he got his results by direct experiment; and the soundness of his knowledge and his ability to apply it were shown in the strength and clearness of his prose; and still more markedly in his polished, smoothly-flowing verse. With him poetry was a natural form of expression. As was to be expected from one of his kindly temperament and lively humor,

* Morton Memorial Volume, p. 190.

he was peculiarly happy in his verses of occasion. But he sounded also a deeper note. In such poems as "The Discontented Island"—a most delicate fantasy, treated with serious purpose and a greater tenderness—he dealt with the deep principles of human nature; and his work of this order, it is interesting to observe, was informed by an imaginative quality that, in a way, was a by-product of the powerful imagination which was a necessary part of his equipment as a creative scientist.

"It is to be regretted that so few of his poems have been published. For himself, he was content with the agreeable recreation that he found in writing them; and with the further pleasure that he found—and gave—by printing one now and then in a dainty pamphlet, illustrated in accordance with his own suggestions, for circulation among his immediate friends. Sometimes, and that was the best of all, he would read one to a few of us gathered of an evening in his library—a room so filled with characteristic belongings that it absolutely was a part of himself. The reading rarely was of set purpose. Something in our casual talk would suggest it; or there would be on an easel a fresh lot of illustrations for one of his booklets, and we would ask for the poem to which they belonged. And then we would have our reading—the charm of the poem increased by the charm of his voice—in quite an accidental way.

"Indeed, it was because everything went easily and a little by chance in those evenings, that they were so delightful. Their only constant and certain quantities were a great friendliness and a flow of brilliant talk, that sometimes held seriously to a single topic the whole evening through, and that sometimes played with a dozen topics in an hour. In those givings and takings of thought he was equally good as a leader or as a listener, and I cannot remember an occasion on which any subject was broached about which he was not deeply and accurately informed. At the end of our talks he left us always the better for his wisdom or his wit: and yet his method was such that, for the moment, we would have the feeling that he was merely refreshing knowledge that we possessed and had suffered to grow rusty, or that his keen comments and lively sallies of fancy were what we were about to say ourselves.

"The charm of those evenings—and it was the same charm that made all who came in touch with him better and happier—was his strong, warm sympathy in the doings and in the hopes of his fellow-men. His manifestation of that sympathy was not careless or fitful.

"The considerate purpose of his life was to add to the happiness of other lives. He believed, and he realized his belief, that only on the lines of reciprocal helpful kindness can the approach to universal happiness be made. Here, in his own words, is the statement of his creed:

"None are alone;
Each hand in hand with each
Is traveling toward the fair sublime unknown.

HENRY MORTON—NICHOLS

Forget thy little self. One moment turn
Thine eyes upon the universe and learn
That thou, and with thee all created things,
Are fellow-architects,
Each one of whom erects
In part, from out this present heaven and earth,
New earths, new heavens of surpassing worth,
Lovely beyond thy best imaginings.

Oh, weary, weeping heart, then turn
From vain repinings at thy state!
With thy vast brotherhood of nature learn
Ever to work and wait.
And rest assured of this, Oh, soul of mine,
Thy essence is eternal and divine,
And shall not share its mortal garment's fate.'"



J. V. Lesley.

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OF

PETER LESLEY

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BY

W. M. DAVIS

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PETER LESLEY

Introduction.—For more than the later fifty years of the last century, the name and work of Peter Lesley were closely bound up with the geology of Pennsylvania. He became assistant on the first Geological Survey of the State in 1839 and drew the geological map that was published in the Final Report of that Survey twenty years later; he was extensively consulted as expert in various geological problems, but particularly in connection with coal, iron and oil; he was director of the Second Geological Survey of the State and closely superintended all of its work. He undoubtedly knew more about the geology of Pennsylvania and was more widely known as representing the geological formations and resources of that State than any other man, but his knowledge ran far beyond the State boundaries.

The two admirable volumes, "Life and Letters of Peter and Susan Lesley," edited by their elder daughter, Mrs. Mary Lesley Ames, of St. Paul, Minn., and dedicated to the younger daughter and the ten grandchildren (Putnam's Sons, New York, 1909), afford unusually abundant and authentic material from which to frame the narrative of this memoir. Sketches by a number of Lesley's associates* have supplied personal estimates of his career; extracts from these latter sources are often indicated by single quotation-marks. My own knowledge of

* B. S. Lyman. Biographical sketch of J. Peter Lesley. Trans. Amer. Inst. Mining Engineers, 1903; 35 pp. and portrait.

P. Frazer. J. Peter Lesley. Amer. Geol., xxxii, 1903, 133-136.

B. Halberstadt. Obituary of J. P. Lesley. Mines and Minerals, xxiii, 1903, 556; portrait.

J. J. Stevenson. Science, N. S., xviii, 1903, 1-3.

J. J. Stevenson. Memoir of J. Peter Lesley. Bull. Geol. Soc. Amer., xv, 1904, 532-541; with bibliography.

A. Geikie. Notice of J. P. Lesley in anniversary address. Quart. Journ. Geol. Soc., lx, 1904, xlix-lv.

H. M. Chance. A biographical notice of J. Peter Lesley. Proc. Amer. Phil. Soc., xlv, 1906, i-xiv.

Lesley's work for a number of years and a high admiration for it, supplemented by personal acquaintance as a junior with him and his family, have given me courage to attempt a task that could have been better done by one of my seniors. The task was undertaken directly after the completion of a memoir of Major J. W. Powell, and grew to be particularly interesting from the contrast in the materials on which the two memoirs are based, as well as from the extraordinary differences between the two personalities that they reveal. The records of Powell's work were found almost wholly in his official reports and scientific articles; no personal letters were available to disclose the more intimate side of his life. Lesley's published work has also been drawn upon as a means of indicating the nature of his studies, but his numerous and voluminous letters, published by his daughter but not necessarily in what might be in more senses than one called the "original spelling," have served as an unconsciously prepared autobiography, revealing his ambitions, moods and difficulties, his discouragements, hopes and successes; and these have been drawn upon largely in the wish to set before American geologists of today something of the remarkable character and the vast accomplishment of a man of an earlier generation, whom most workers at the present time can know only by name.

Ancestry.—Peter Lesley, the fourth of that name in direct succession, was born in Philadelphia on September 17, 1819. The first of the four Peters was a miller in Fifeshire, Scotland; the second, a carpenter or cabinet-maker who came from Aberdeenshire to Boston in the 1700's, and went thence on foot to Philadelphia, where he established his shop. The eldest son of his second wife, Catherine Ketler, of German origin, was the third Peter, born in 1792(?). He became a cabinet-maker, like his father, and married in 1816(?) Elizabeth Oswald Allen, daughter of John and Sarah Allen, of Charlestown, Mass., and later of Philadelphia, where Allen was a printer. The home of Peter (the third) and Elizabeth Lesley, on Vine Street below Sixth, was one of small means and numerous cares; into this family the fourth Peter, the third of many children but the first of eight sons, was born. Although baptized "Peter Lesley," like his forebears, our pro-

tagonist is known to the geological world as "J. P. Lesley," because about 1850 he prefixed the letter J. to indicate "junior," and abbreviated Peter, a name that he did not then like, to its initial. In later years he came to prefer his baptismal name. His varying usage might well confuse the unwary reader: the first report of the Second Geological Survey of Pennsylvania bears the name of J. P. Lesley on the title page; in the list of officers the state geologist is given as Peter Lesley, and in a sketch of survey history one of the early workers is named Peter Lesley, Jr.; but these three names all refer to one individual.

Boyhood: 1819-1834.—Young Lesley was a nervous and sensitive child, abnormally near-sighted; he considered himself homely and was timid accordingly. Many years later an old aunt told him that he had been a beautiful child, and he remarked:—"I must have been surrounded by wise people, for I grew up with the depressing conviction that I was ill-favored"; but he added:—"My life would have been made much easier for me, if somebody had told me that I was a handsome boy." He had an early liking for geography and maps and for making imaginary journeys, in which he took great pleasure. He later tells that he had practice in the use of tools, that he made toy machinery in his father's shop, and that with his brothers he was "drilled daily by his father in describing events so that they could be understood, and in drawing every kind of object in its true proportions." As his father was an accurate draftsman, drawing was fortunately taught the boy not simply as a manual exercise with a pencil, but as a means of expression; his professional work in mature years shows how frequently he made use of this valuable art and how notable a success he reached in it. In his later boyhood (1836) he wrote:—"Father, would you believe it, I really think I have received more benefit and good, wholesome learning at our breakfast meals, than in all the schooling and collocation of ten years"; and in a much later reference to early home life he says:—"I owe all that I am, and have been able to do, to the early training which I received from a very wise father and the artistic nature of my mother. * * * I am proud of my mother's family, humble, poor, virtuous, benevolent, beneficent, endowed

richly with the best faculties of the heart and head of the old New England or English stock."

Under parents of such quality, the young family was carefully nurtured. "Neither our reasoning faculties nor our imagination were allowed repose, and no mischievous or silly literature entered the house." Lesley and his brothers were sent to the best schools and were not only taught Latin and Greek, but had private lessons in French and German. It appears from the records by Peter the fourth that his father, Peter the third—the second cabinet-maker—"was a lover of the English classics, read aloud to us modern and ancient histories, and was thoroughly versed in theological controversies:" he evidently had an exceptional interest in the intelligent education of his children, and as a devout Scotch Presbyterian and an ardent church-goer, he as evidently had strict views as to religious training, for young Lesley ordinarily heard three religious services every Sunday, besides attending two sessions of Sunday school. Thus the boy learned the Bible, particularly the Old Testament, almost by heart: he devoured books and remained an active reader on many subjects all through his life; his favorite books he re-read many times. A letter written in his fifteenth year, describing a political meeting, is in thought and phrasing a superior composition. The youth showed great earnestness of feeling and fortunately formed the habit of saying what he felt; the outspoken expression of his inner thought, sincere, absorbed, unaffected, free from self-consciousness, was a marked characteristic of the man all his life. In 1835 he wrote to his father of a journey northward:—"How shall I describe midnight on the Hudson! My soul was lifted it seemed higher than ever I felt it before, towards the throne of God. Joy such as the lover of nature's pure romance alone can feel, I felt. * * * Oh, evening on the Hudson! Give it me even before the Mohawk's glorious scenes, whose western sky and rolling mists present a splendid conflagration of a world. Italia's scenes are fair (so travellers say), but give me Hudson's flood at eve of day." This, whether original or quoted, is surely a touching revelation of poetic feeling in the early years of a young man brought up as a Scotch Presbyterian in Quaker Philadelphia: yet when the

grown man, forty years later, found a package of his own early letters to his father, he tore one up, "it was so terribly soft."

First Geological Work, 1839-1841.—Young Peter went at the age of fifteen (1834) to the University of Pennsylvania, where he took high rank, gained membership in the Phi Beta Kappa, and received the bachelor's degree in arts in 1838; three years later he was given the degree of master of arts. He grew tall rapidly and his strength was uncertain. Although it had been intended that he should devote himself to the Presbyterian ministry, the fear of the bad effects of continued college study on the young man's health led his father to accept the advice of his friend, A. D. Bache, afterwards Superintendent of the Coast Survey, that the son should have a season of outdoor work on the Geological Survey of Pennsylvania, which had been established shortly before under H. D. Rogers, who was himself only twenty-eight years old when he assumed the office of director in 1836. Thus there was added to the staff, in great part hardly more than boys, still another young and inexperienced member, whose geological training really began in the field where he was given his tasks; for nothing was then more difficult than to find persons of scientific education, suitable for survey duties. So in 1839 young Lesley, before he was nineteen, began geological surveying, on which he then spent three summers. He worked for a time with Whelpley and Henderson, then was set to collecting information from collieries in the anthracite basins; in 1840 he made a topographical and geological sketch of the Siluro-Devonian belt from Harrisburg northeast to the New York State line; in 1841 he made a reconnaissance of the bituminous coal basins in the forest-covered wilderness of north-western Pennsylvania, and then returning to the anthracite region completed a map that Whelpley had left unfinished two years before—all this before his twenty-second birthday! One of his assistants on the Second Geological Survey many years later describes this early work as "mere reconnaissance," yet he adds that when it was reviewed in the '70's it required little correction; for "the skill with which Lesley and his youthful colleagues unravelled complicated structure was little short of divination."

Lesley's letters from the field were full of descriptions of scenery; his manner of writing about the people he met in villages and on farms shows him to have been a thorough democrat. That first summer in the anthracite coal regions, the sober-minded, poetic-souled young man, then in his twentieth year, took with him Cowper and Carlyle for reading and carried along his flute for pleasure; but he was reluctant to play it before the young people of the villages where he was quartered. He rose at five o'clock, read a chapter "in the German," and prayed for grace and protection for the day, which was spent in the saddle over the hills. Before he was twenty-one, his work gained praise from his chief, who gave him credit "for the faithful and laborious manner in which he had unfolded the geology of the occasionally complicated zone of country, and for the accurate and neat map which he had constructed of its formations and topography."

Early Appalachian Study.—Lesley himself presents fifteen years later a delightful record of survey work in those earlier days:—"In Pennsylvania paleontology and detailed local stratigraphy were impossible; we were untrained in both. * * * Nothing remained to study but dynamic forms; and these so numerous, so grand, so variously grouped that they excited a perpetual enthusiasm, and led us on to infinite research. * * * They were a world of the exhibition of natural forces by itself, and as such we took possession of it and settled in it as our fathers did in the valleys themselves, and thus became * * * not geologists in the full sense of the term, but topographers, and topography became a science and was returned to Europe and presented to geology there as an American invention. The passion with which we all studied it is inconceivable, the details into which it led us were infinite" (Coal and its Topography, 1856, 123, 124). Nearly forty years after the First Survey, Lesley delights to give credit to his early fellow-workers for the first explanation of anticlinal valleys in 1837-38. Then "first appeared before the eyes of students of the science on this side the water, those symmetrical vaults and basins into which the seven-mile thick earth-coat of Old-Age Rocks [this phrase is his substitute for Paleozoic] had been pressed; to heights higher than the

Himalaya Mountains, and to depths deeper than the deepest ocean soundings. Arched roofs of Coal Measures, invisible to common eye, were now seen by the geologist's instructed vision spanning in air the interval between the crest of the Allegheny and the crest of Broad Top—mountains forty miles distant from each other. * * * Before these stupendous structures, some of which must have been six or seven miles higher than the present surface, Alps and Andes hide their diminished heads. In 1838, the erosion of the earth's surface was first clearly revealed to geologists in America in all its magnitude, and took its place as prime factor in their calculations. It was not adequately felt by European geologists until long afterwards. * * * The doctrine of vast subaerial erosion, which now plays so prominent a rôle in all discussions of the physics of the earth, and especially of dynamic and sedimentary geology, may therefore be justly called a Pennsylvanian discovery, dating from the years 1837 and 1838. * * * In 1838 this master-key thought in structural geology became the common property of the Assistants on the Pennsylvania Survey" (Second Geol. Survey Penna., Vol. A, 1876, 85, 86). But the most touching reference to this early work is found in a personal letter dated January 17, 1887:—"I commenced my dictation [of a Survey report] today, after a rest of half a week * * * and dictated with great ease the southern outcrop along the Kittatinny Mountain, describing the water gaps in succession. * * * It is intensely interesting, in spite of my long acquaintance with the subject—long enough to wear out any amount of enthusiasm. It was in 1839 (48 years ago) that I found the first block of ore in No. V. ever seen east of the Susquehanna—at Port Clinton, one fine morning while I was fighting my way through the underbrush and over the rock slides along the bank of the Little Schuylkill, at the foot of the mountain. I was as usual alone, in a forest, utterly secluded from men and men's affairs. * * * I could only see the beautiful water by my side, and the rocks over which I stumbled, the trees which thickly covered the steep mountain slope, and now and then a fleck of sky. How happy I was in those days of strength and zeal and poetry! How pure life seemed; how unending the career of mortal man!"

Theology and Geology at Princeton, 1841-1844.—Three seasons in the field seem to have strengthened young Lesley, so that at the end of the summer of 1841, when the Survey was disbanded for lack of appropriations, he began three winters of study in theology at Princeton. Some of his time there and during his vacations was given to work for Rogers on the geological map and sections of Pennsylvania: the compilation of the base was a difficult task demanding great patience and skill, for the best existing maps were full of inaccuracies and blunders, and the different parts had to be adjusted so as to humor their errors when brought together. The mountains, which had been the chief guides of the geologists, were carried over from county to county, as the best guides to the corrected representations of the minor watercourses. The county lines were forced into adjustment from both ends of the State to the Susquehanna River, where the total error accumulated; then this gross error was distributed backward east and west over the whole State. The work occupied eighteen months in 1842 and 1843.

Lesley's letters of this period show a curious mixture of the two rival 'ologies between which his interests oscillated. The more earthly one nearly gained the day in 1844, when having in his twenty-fifth year completed his course at Princeton and been licensed to preach by the Presbytery of Philadelphia, he was again offered a place on the Pennsylvania Survey by Rogers; but it was defeated by his desire for foreign travel and theological study in Germany.

A Year Abroad, 1844-1845.—Lesley proposed to cross the ocean in the steerage of a sailing vessel, so as better to prepare himself for preaching to poor parishioners later; his father persuaded him to be content with the second cabin, which he found none too comfortable; and this experience of humble travel seems to have been sufficient, for a year later he returned as first-class as possible, yet still with the unimpaired determination to follow his chosen career in the service of the poor and the ignorant. He brought back seven volumes of closely written diaries, illustrated with many sketches of scenery and architecture, for a large part of his traveling had been done on foot and to one side of beaten tracks. The diaries consti-

tute an unusually interesting record of a year abroad by an unsophisticated traveler at a time of unconventional travel.

Young Lesley stopped briefly in England and then passed a month in Paris, where he worked hard on French, but without much success; he liked the language less than the people. He saw French ways more truly than many another American, for he wrote:—"There is a show of simple-hearted affection among all classes of the French population which impresses a stranger with a very favorable idea of their domestic life." In Paris he met Elie de Beaumont, gave him a copy of the Bear Gap section in Pennsylvania, and received from him the loan of a copy of "his large and very beautiful geological map of France" for study. In early August he left Paris—a slender young fellow, a little over six feet in height, clad in a belted blouse, wearing spectacles and carrying knapsack on back and umbrella in hand—for a trip down the Seine by train and on foot. He notes all sorts of things:—"The scenery of the Seine bears much resemblance to that of the Mohawk, and from the same cause; a wide valley of denudation; excavated in a rolling country of nearly horizontal dip; and filled and flattened by diluvial and alluvial deposits"; but later, on reaching Duclair and Caudebec near the river mouth, he writes of architecture, history, and religion, and not of the superb meanders that the river has there incised. He made a point of seeking out French protestant clergymen, with some of whom he developed warm and lasting friendship. From Normandy he passed to Brittany, where he had a race with the tide across the sands from Mont St. Michel, reaching the mainland wet to the knees and exhausted; then to Auvergne, where he seems somewhat disappointed because the volcanoes are extinct and the lavas cold; "the exhibition is over," is his brief comment, as if he ought to have gone there earlier! Next south into the Pyrenees, then across the lower Rhone and past Grenoble to Geneva, where he met several noted Swiss divines.

It was at this time that he saw the Jura Mountains, which have so often been compared with the Appalachians, but never more forcibly than by the young Pennsylvanian when, fourteen years later, he recalls this part of his foreign journey: he counted himself "fortunate in being the first geologist who had

an opportunity to approach the dynamic phenomena of the Jura with an American eye, trained on this typical [Appalachian] ground. * * * The moment, therefore, one of us beheld the ranges of the Jura, with their combs and offsets, their vast escarpments, and far glittering white gaps, he felt at home among friends where geologists born among them felt that they were strangers" (Coal and its Topography, 1856, 122-124). Finally he went northward to Halle, and there for six months he studied German and theology. Geology was laid aside: the young theologian said:—"I feel an ever-increasing, ever-more continuous desire of seeking the salvation of the souls around me; yet this desire is never gratified." He found Tholuck, whose lectures seem to have attracted him to Halle, less narrow than some of his American friends, and free to declare that many things in the Bible are not true. Some of the spiritual debating within himself he wrote down; his position was staunchly conservative.

In the spring of 1845 Lesley made a short visit to Berlin, where he saw the famous theologian, Neander, and called on "little old von Buch," who was polite, but not cordial. The young Pennsylvanian was surprised to hear no mention of dynamical problems from the great German: all the talk turned on lithological comparison and paleontological identification. "When I said I thought the Jura just like the Allegheny, he looked at me a decided No; for he had but one idea—the Jura limestone does not cross the Atlantic. Rogers will wake them to new life when he comes to Europe this summer." A touch like this shows that geology was still a strong undercurrent in Lesley's thoughts; his dismay at the failure of an old master to see new light was an experience that others have shared. After another month in Halle, he embarked in a sailing vessel at Bremerhaven, May 9, and crossed the Atlantic in six weeks.

Preaching in Pennsylvania, 1845-1846.—After his return he acted for over a year, 1845-1846, as colporteur for the American Tract Society among the country folk of secluded villages and farms in the forest counties of Pennsylvania, by whose benighted condition he had been deeply touched during his survey work five years before. Lesley took this engagement with great seriousness. He wrote at divers times:—"The vastness

and importance of the work I never saw rightly until yesterday afternoon, when I felt myself suddenly crushed down by it. * * * I feel now that *for me* there is nothing but this worth living for. * * * Preaching five or six times a week is not often called for. I feel a little weak, but otherwise pretty well. Am exciting an interest in the county, and have every prospect of succeeding in getting these wealthy farmers and iron-masters to support the good work among their own hills. I love dearly to lay their duty before them and see how earnest and solemn they become. * * * I wish you could see me from day to day, how happily I find myself in the households of the good people. The only trouble is that I am too much among the rich and well educated, and therefore too well used." He was imprudent and independent enough to like some of the tracts that he had to distribute better than others, and gave them the preference, a discrimination that was disapproved by his employers. But the work proved too heavy for him, and after two seasons of constant mental excitement, bodily fatigue, and exposure, his itinerant preaching had to be given up. Fortunately a letter came in November, 1846, from Rogers, who was then living in Boston and who had an immense amount of undigested geological material on hand, which he was trying to put into shape for publication, largely at his own expense. Of this Lesley tells that his former chief "requests me to aid him in preparing to present his report to the Legislature in the spring in its final form, and offers me great facilities for study and observation, and \$400 for my services for the four months." The young theologian thereupon went to Boston and thus began his association with New England, where the deepest pleasures of his later life seemed to have been found, though his tasks and duties were chiefly in Pennsylvania.

Geological Work in Boston, 1846-1847.—Could there have been a greater contrast than that between the summers, which Lesley spent preaching and distributing tracts among the uneducated country people of central Pennsylvania, and the winters following in and near Boston, where, besides working with Rogers, he met Channing, Parker, and Clarke, Emerson, Garrison, and Phillips, Agassiz, Lyell, and Guyot. Little wonder

that the young orthodox licentiate felt some astonishment and confusion of mind at what he daily saw and heard, and less wonder that his father, on learning of it, wrote: "I am very solicitous about your exposure to being drawn away from the simplicity of the Gospel in the cold Unitarian atmosphere of Boston." The son guilelessly replied: "Your fears are natural, but I trust groundless." He was seldom a good prophet, and never a poorer one than in this instance.

Lesley was precisely the right man to enjoy the Boston of that time, for it was a tolerably serious city and he was a very serious young fellow, however much he enjoyed a certain kind of fun at times. He had had a much wider and more varied experience than most young men of his age and period; he had acquired an astonishing amount of information on many subjects, and he possessed a "generous, appreciative sympathy with another's views that added such a charm to intercourse with him. His skill in conversation was wonderful, and he delighted to practice it * * * for the pleasure or profit of his companion as well as his own." He eagerly took advantage of his new opportunity. "What a strange society," he writes, "is this! Not a man, not a woman I meet, but has a distinctive character, of which I can learn something either by precept or example." After a year and a half in such company he wrote frankly to his father:—"My stay among Unitarians has changed me no doubt, but not in any way I think that your views of gospel truth or hearty piety would cause you to regret. * * * But I am changed and am still changing." His father wrote again: "I cannot divest myself of anxiety about your stay in Unitarian society." The sequel shows how fully these fears were justified; for, although during the son's change of opinions he relieved himself by calling the Unitarians some hard names, he found warm friends among them, and in later years he more openly accepted their liberal faith, though he never joined their organization.

In the meantime young Lesley was working as draftsman for Rogers, duplicating the map and sections that he had previously drawn at Princeton; and in June, 1847, he wrote home:—"The map [of Pennsylvania] * * * is surprisingly beautiful, and will receive the last stroke perhaps on Thursday

next. Two more days will be required for laying in the tints upon the one we mean to color, and then I shall be a happy man." A few days later he adds:—"I put the last stroke to the map, and turned to coloring the original, which I half accomplished, beginning with fear, but ending in delight; it excels our hopes." This is the original of the fine geological map of Pennsylvania that was printed in Edinburgh and published with the two-volume report on the Geology of Pennsylvania in 1858. While working in Boston the young draftsman felt a warm friendship and high admiration for Rogers; indeed, these feelings were maintained longer by Lesley than by most of Rogers' early assistants; but the friendship weakened afterwards when the two were again associated in geological work; and sad disappointment, with violent revulsion of feeling, was caused by the manner of publication of the survey report twelve years later, when the geological map of Pennsylvania appeared without Lesley's name upon it!

Preaching in Milton, 1848-1850.—As the work for Rogers was approaching completion, Lesley looked around him for some other occupation. Opportunity to serve as a Presbyterian minister at Williamsport, in northern Pennsylvania, had been opened to him in the spring of 1847, but he seems to have felt no disposition to return among the people to whose service he had in his earlier enthusiasm wished to devote his life; he had come to prefer a community of greater intelligence. He wrote:—"From all I can learn of it by intercourse with the orthodox brethren here, I decidedly prefer the Congregational form of government and the whole church polity of New England, and the tone of feeling and religious spirit of the country, to their counterparts with us." It was a good fortune, in view of this change of heart, which was only the prelude to a still deeper overturning, that he was invited in the late summer of 1847 to preach for a few Sabbaths in a Congregational church in Milton, a delightful village on the south of Boston, for this invitation later resulted in a call to fill the pulpit there for an indefinite time as well as in life-long acquaintance of great import: so to Milton he went early in 1848.

Life in Milton appears to have been very happy, as his neighbors were cordial and congenial and he was near enough to

Boston to enable him to continue the friendships that he had formed there. Of the Anniversary meetings in May he said:—"I attended none of them, for fear of their excitement. * * * It is a perfect Carnival of Benevolence, a sort of spiritually Bacchanalian orgie. Shawls and white cravats filled the city:" but he heard Emerson lecture, he dined with Wendell Phillips, and borrowed books from Theodore Parker; he "supped with John [M.] Forbes and discussed the new [California] gold fever, the British National debt, repudiation, Association and the theory of central heat; justice, temperance and coal mines." Whether "central heat" was theo- or geological does not appear explicitly, but "Association" was presumably that of the Congregational ministers of his county, with which he was not in harmony, although he insisted that he was as orthodox as his professors in Halle; indeed he could not at that time have been very heterodox, for at a still later date he prepared a lecture in which he referred "all ancient history back to the facts of the Noachian Deluge." But there was already much question as to his continuing to occupy the Milton pulpit: he did not like to take money for preaching, he refused to be pledged to any system, and would not conceal his views. "Here lies the whole difficulty. I do not wonder that they, some of them, feel afraid that in licensing me they encourage heresy, and in recognizing me afterwards they admit a firebrand." He was always positive in his beliefs, whatever stage he had reached in his religious progress; he was outspoken in expressing his convictions. He wrote:—"I am determined beyond all recalls, to sacrifice home and friends and name and life itself to what I believe to be the Truth, so help me God and all good angels. I have lived to learn that the fame of the world is a folly, and the comforts of life are worthless, and that nothing but Truth is worth living for, or dying for. Nor will I sacrifice an iota for any worldly consideration. * * * I have higher authority and a diviner power within me than that possessed by any human organization, however perfect. * * * I feel the strongest leaning to an open utterance of opinion, let the consequences be what they may;" and again:—"I always say what I think, at all times, on all subjects;" but his acts were not so uncompromising as his words; within the year he generously

accepted a caution from a minister for whom he preached not to touch moot points: "Of course I would not." It was perhaps as much from a half-conscious premonition of his later discontent with preaching, as from an ever-ready willingness to suffer martyrdom for the truth as he saw it, that he said:—"If I be excluded from all pulpits, I shall go to cabinet-making and serve God better there than as a time-serving Minister in a pulpit."

Engagement and Marriage, 1848-1849.—Among his friends was one Lyman, whom he had known in Halle four years before, and whom he seems now to have seen at the house of another Lyman in Milton, and whom he again met when he was in the Connecticut Valley for a short time in the summer of 1848. Regarding his stay there two items deserve mention. One is geological: he writes that the meadows of the valley "are not alluvion, made by river sediment; but are the last throw-down of the diluvial waves in their draining off, impeded by the great trap dykes thrown obliquely across the valley;" we shall later see how Lesley, when he returned to geology in Pennsylvania, again made use of the diluvial flood, and still later how he gave it up. The other item, found in a letter of August 6, is personal:—"I made some valuable friends at Northampton [Mass.]" ; among them were the family of Mrs. Lyman, of whom much more is to be told. Later in the same month he wrote to his father of hearing the Phi Beta Kappa oration at Harvard, which gave him high delight. Another member of the audience was Miss Susan Inches Lyman, whom Lesley had met at her home in Northampton shortly before, where, as was afterwards confessed, they 'instantly felt * * * that they belonged to one another.' She also wrote in August:—"I enjoyed the Phi Beta unspeakably." If any historian be tempted to quote these phrases to the advantage of the orator, Dr. Bushnell of Hartford, he ought at the same time to recognize that the young writers were predisposed to enthusiasm, for their engagement was soon afterwards announced. Their daughter and biographer says that the lovers were "probably quite unconscious of each other's presence"; but the opposite hypothesis seems permissible, as Lesley knew of the oration before he became acquainted with the Lymans

in Northampton. He wrote to his father, October 9, 1848, announcing his engagement to "a very lovely woman," who "has neither health nor wealth at present," but who "is all that I can desire."

The Lyman Family.—The Lyman family with which Lesley thus became connected was indeed a notable one. The father, Joseph Lyman, son of a Northampton farmer, was born October 27, 1767. An accident in childhood was the cause of such delicate health that his parents decided to send him to college, instead of keeping him on the farm. He therefore went barefoot and in a homespun suit, to Yale College, where he graduated in 1783. After practicing law for a time in Worthington and Westfield, Mass., he returned to Northampton, where he came to be highly regarded, and as "Judge Lyman" became widely known and respected. He was 'a devoted friend, thoughtful, clear-sighted, reverent, a lover of religious liberty, a self-sacrificing philanthropist, an ardent patriot, diligent in business, a cheerful giver.' The mother of the family, Anne Jean (Robbins) Lyman, born in Milton, Mass., June 3, 1789, was a woman of rare character, who at twenty-two married, on October 30, 1811, a widower twice her age, and 'became at once his cordial companion in all his active work, the head of an already large household [five step-children], a power in the village life, a mover in social activities, and foremost in such reforms as the time demanded.' Their home was open for hospitality the year round. Mrs. Lyman's vigorous mind and remarkable character have been admirably set forth by her daughter, Mrs. Lesley, in a memoir, "Recollections of my Mother," referred to below.

The daughter, Susan, was born April 7, 1823, the fourth of five children, who were taught by their mother, among many other good precepts:—"It doesn't matter in the least what other people do to you, but it matters very much what you do to other people." Her parents had left the old church—the church of Jonathan Edwards at an earlier time—to become Unitarians, and Susan was brought up in that simple faith; this must have had much effect after her marriage in the further liberalizing of her husband. Indeed he had written her during their engagement:—"I am not only willing, but have

already begun to sacrifice my views and prejudices to smooth your way." During visits to New York in her girlhood, Susan Lyman had come to know Isaac T. Hopper, Sidney Howard Gay, Lydia Maria Child and others, whose names mean much to those familiar with the early anti-slavery movement: thus began her deep and long-continued interest in problems of poverty and distress. As a girl she was an active reader of good books in a family where reading was one of the recognized needs of life. She wrote in 1841 that her school friend, Lucretia Hale, had given her "Jemmy Lowell's poems; are not many of them perfect?" Her father died in 1847, her mother in 1867.

An incident illustrative of the simplicity of New England life at that time occurred while the Lymans, mother and daughter, were in Cambridge in 1848, on the occasion above alluded to. The daughter then wrote to a friend:—"I have enjoyed these two days highly from the fact that James Thayer and Chauncey Wright have entered Harvard, and James without a single condition. Mother is a little too happy. She spent this day in preparing his room—putting down a carpet": for the daughter had seen her mother and her aunt set forth, arm in arm, with hammer and tacks, to fit up the freshman's quarters. Thayer was later an eminent professor in the Harvard Law School; his classmate, Wright, became a well-known mathematician, with a strong bent toward philosophy.

Peter and Susan Lesley.—It has been noted above that Susan Lyman had "neither health nor wealth" at the time of her engagement to Peter Lesley. He also was not strong and had no established means of supporting himself. Naturally, therefore, the engagement was opposed by prudently solicitous relatives and friends, but without avail. The young man, with all the confidence of inexperience, wrote to one of the remonstrants:—"It comes of the unnatural state of our social life that we consider it needful to begin married life with a provision of wealth held in reserve," and the improvident pair—he, a tall, awkward, ungainly fellow, careful and orderly in his work but impulsive in thought, brusque in manner, imaginative, witty, excitable, inclined to melancholy moods and delighting in change; she, a graceful girl, calm and beautiful, with much

social tact, patient and hopeful, unmethodical, loving a quiet life not too much broken by variety—were married, on February 13, 1849. Their engagement had lasted only three months. In spite of all proper predictions, they lived more than fifty years together in closely united happiness; for both were of deep and sincere feeling and absolutely trustful of the other, morally and intellectually honest and fearless, little mindful of material matters but caring greatly for spiritual things, full of exalted enthusiasms but without pretense, and always unselfishly devoted to good causes. Theirs was not the untried pleasure that may come from a life of assured wealth and ease and comfort, but the well-proved happiness that springs from mutual confidence and support in trials of body and mind—a happiness that was tested through years of hard work and narrow means before established position and simple competence were reached. Their life was one in which each demanded much and received much from the other, although as to which one of the two made the greater demands and which one the greater sacrifices, nothing need be said to those who know the ways of a husband devoted to his science and of a wife devoted to her husband.

A little story cheerfully told by Mrs. Lesley seven years later, when the pair were living very economically in Philadelphia, may be here introduced: "On Monday morning early [note the day of the week!] we were astonished by the sight of four gentlemen. * * * They were Professor Hall of Albany, Prof. Haldeman, Dr. Le Conte, and Dr. Henderson. They were all day in Peter's study, having great scientific sympathy and very animated conversation. At about twelve, Peter came down and said that they were all going to stay to dinner. I had been sick with a stiff neck and sore throat for three or four days, but I jumped up to calculate my resources. My woman was in the midst of her washing, and we had calculated on a very mean dinner of cold scraps. But Martha ran out and hired a cook, and bought an elegant pair of fowls; and to a confectioner's and got pies. And at two o'clock precisely came off one of the nicest of dinners, with Mary, all dressed and waiting on table, four kinds of vegetables, a bottle of sparkling Catawba and everything to match. Peter had not calculated

on anything so fine, and was all struck of a heap at the sight.

* * * At five o'clock in the afternoon our friends left."

But the same faithful wife also wrote, many years later:—

"Do you know that on Friday, April 7th, is my birthday, and that I reach my threescore and ten years? What a happy life I have had, how blest in every way!"

Married Life in Milton, 1849-1850.—The young couple went to Milton, where they lived in the simplest manner. One said: "Our tastes click together like two clocks;" and yet how differently were they compensated! Before their marriage the young man had written to the young woman:—"You have long already discovered in me an inconstancy of feeling which may trouble you. But the changes are so rapid, that like the various impulses of the terrestrial magnetism, they practically hold the needle steady in the end. And in you I see what will be full compensation, a singular and admirable steadiness, which I know not how to praise or love enough;" and this was a true judgment. The young husband was happily right again in writing to his father soon after his marriage:—"I have a notion that in spite of all prophecies adverse thereunto, our destiny is to grow old together."

Lesley preached in his small church and was beloved by his flock; he eked out a slender salary by work of various kinds. In the winter he wrote magazine articles and lectured on such subjects as "The aboriginal settlement of Europe"—on which there must have been at that time free play for the imagination—but the supplement to his income thus secured was not large, for he tells:—"I have lectured twelve times this winter [1849-50] and it has brought me in \$70." In the following summer he did odd surveying jobs for Rogers in Pennsylvania, on which he was away for weeks at a time, and in the winter of 1850-51 he gave much work to a map of Virginia, presumably for W. B. Rogers, brother of the Pennsylvania geologist. Books then and later afforded a favorite entertainment at home; Mrs. Lesley writes:—"We have been reading together a book that has delighted us much, 'Earth and Man', * * * it is by a Mr. Guyot, whom Peter has seen." Lesley wrote: "The scientific Association has been meeting all last week and this [Aug. 14, 1849] at Cambridge. Susan and I have there-

fore made our headquarters here at — [in Medford] and I walk to Cambridge [three miles] every morning and back in the evening. The sessions have been of high interest. The walking has done me material benefit. I need more exercise than I get." His wife spent some time during an illness, later in the year, with friends in Cambridge; the husband writes that what with her being "ten miles off, beyond the city [Boston], and my sermons and lectures before Lyceums, and goings to and fro between Milton and Cambridge, and house-cleaning, furniture-seeking, and fixing up generally have made me a slave without manacles."

During all this time, Lesley had held no regularly sanctioned appointment in his Milton church. Early in 1850 the Association of Congregational ministers of his county having refused, at the instigation, it was said, of the Tract Society of Philadelphia, to ordain him, and his own church not feeling ready to take the matter into its own control, he withdrew and, followed by part of his flock, continued for a time to preach in the Town Hall. He published a statement of his position, 'but it apparently had hardly any circulation, for almost the whole edition was, he understood, bought and suppressed,' and he himself soon lost interest in the discussion. During the earlier progress of this question he had written to his future wife:—"The affair of the Association gives me no uneasiness and very little trouble, for I attend to it only when I go to town [Boston] on Mondays, and when I would not wish to study. As to its future consequences, I refuse absolutely to consider them. I have nothing to do with them." It was apparently of this affair that Lyell wrote:—"A young man of superior talent, with whom I was acquainted, who was employed as a geologist in the State survey of Pennsylvania, was desirous of becoming a minister of the Presbyterian Church. * * * He was unable to give satisfactory answers to questions respecting the plenary inspiration of Scripture, because he considered such a tenet, when applied to the first book of Genesis, inconsistent with the discoveries now universally admitted, respecting the high antiquity of the earth and the existence of living beings on the globe long anterior to man" (Second Visit to the United States, 1849, 1, 218). Lesley heard of the story through

Rogers, who was then in London, and said that Lyell was quite wrong. "Who told Lyell I cannot imagine, unless it might be Sumner or G. Ticknor, and none of them knows anything about it," but there was some truth in the story.

Lesley's Hobby, "Arkism."—Mention may be made here of Lesley's lifelong hobby which he called Arkism, a curious sort of linguistic and symbolic investigation, possibly an outgrowth of his literal acceptance of the truth of the Bible acquired in boyhood during his assiduous attendance at church and Sunday school in Philadelphia. 'His view was that after the Noachian deluge, or whatever may have given rise to the myth, the Ark and its accompaniments, the mountain and the waters, became sacred objects that were made by the priests to recur symbolically in art, especially architecture, or in words, singly or variously combined, in a thousand different forms.' The pursuit of this mystical idea carried him into remote fields of ancient history and dead languages, and involved many speculations that now seem over-fanciful; but he had great pleasure in giving spare time to it and expressed himself with his usual enthusiasm and positiveness about his results. "I shall yet maintain my position," he wrote in 1849, "and prove that chess is a Druid game symbolic of the Deluge." In the following year, he said:—"For two days I have been hard at work upon two of the radicals in Medhurst's Chinese Dictionary, and have succeeded in exhuming materials by which I can finally demonstrate some very troublesome conjectures of mine upon certain things relating to the south and southwest of Asia and of Europe." Five years later:—"Did I tell you it struck me the other day that the political name Tory is a true Arkism, *Tori*, and equal to Dorian, Druid, etc.? Observe it is the mysterious name of the *High Church* party. Yesterday I was enchanted by lighting on a sentence in Harrison Ainsworth's 'St. James.' He describes the trial of Sacheverell, in Queen Anne's time. and says that the vast mob came with an 'Oak Leaf' in their hats, the distinguishing badge of the High Church party. You see how entirely this confirms my conjecture that the Tory party is the modern representative of the exclusive Arkite Clerical Aristocracy, the Druids of old." He compared his research in Arkism to that of a paleontologist, who had quarry

men collecting for him:—"This is precisely what I want so much to do in my own field. It is high time I had students or boys at work analyzing the different languages of the world. And if I can only pursue such a system ten or fifteen years, I shall attain wonderful results." Through his abundant reading Lesley had come to know so much more of Egyptian hieroglyphics, the Abyssinian calendar, the Sanscrit and other alphabets and various recondite subjects, that he could easily overwhelm any objection to his theories, and thus was in the dangerous position of having a difficult field pretty much to himself.

Return to Pennsylvania and Geology, 1851.—The spring of 1851 found Lesley once more in Pennsylvania, and as a result of his absence his little church in Milton languished and dissolved. He was set to work on private surveys under Rogers, mapping anthracite coal basins near Shamokin and Pottsville, congenial tasks into which he entered with his usual enthusiasm. "The sense of returning vigor, * * * the relief which my brain experiences, are unspeakable." He spent a day of rest and reading with an intense relish of liberty. Thus, with all his devotion to the ministry, geology came to the front; indeed, even while in Milton he had said that the facts of physical geology gave his soul its life. For part of the summer his wife was also at Pottsville, where Peter W. Shaefer, a mining engineer, the "Shaeferlein" of later years, became one of their close and lifelong friends. The season was further memorable for meeting two Swiss scientists. One was Desor, "who although born in the Jura and bred in the Alps, expressed unbounded astonishment and delight at the first fair sight he got of the erosion of our anticlinal valleys." Lesley found him most entertaining and invaluable as "company at meal times." Mrs. Lesley's remarks about him are not flattering to American geologists, for she described Desor as "entirely free from the usual vices of scientific men. He seems never to think of himself or of his own advancement, never makes any secret of his discoveries, is not afraid of other people at all; * * * we call him our sunshine." The other new friend was Lesquereux, the famous paleobotanist, a sweet and gentle spirit, who had had to give up his professorship at Stutt-

gart, where he was much honored and beloved, because of deafness, and who had come to America because Desor, who had the greatest affection and respect for him, advised that his five sons would have a better chance here than in Europe. Of Lesquereux also Mrs. Lesley writes in the light of contrast:—"He has all those lovely ways that one rarely meets with in our countrymen." Lesquereux did much work on fossil plants for the Pennsylvania survey, and Lesley later wrote an affectionate memoir of him which he read before the National Academy to the pleasure of his fellow Academicians.

The winter of 1851-52 was spent in Milton again, where Lesley and his wife always found fond relatives and warm friends; but in the following summer the beloved New England village was given up for Philadelphia. Lesley went there alone first, still loving to preach, and indeed preaching on the way at Northampton, but feeling that his work thenceforward must be in science. His relations with Rogers had by this time become strained, perhaps because they were 'temperamentally antagonistic: both were extremely nervous men, and probably suffered from the irritability common to such sensitive physiques.' Without the aid of his senior, the junior geologist found it difficult to find employment; he must have been hard put to it for a time, for in April he wrote to his wife:—"I wandered all day yesterday about the streets. * * * I sought out the objects of human woes among the crowds, stood and looked at the woe-worn apple-women, planted myself on the wharfs for an hour at a time * * * sympathizing with the seedy old gentlemen in scrimped coats. * * * A profound hopelessness and an exhaustive criticism of the instability and general unsoundness of all things blows upon me like an enervating sirocco from the deserts of No Faith." Many another has had times of despondency under like circumstances, though perhaps without Lesley's resource of being able to hold "gloominess in a very effective and wholesome check" by looking at woe-worn apple-women and seedy old gentlemen in scrimped coats. But it must be remembered that Lesley's impressionistic feelings and therefore his letters, which reflected his every mood, frequently changed their tone; he might be optimistic on one page and pessimistic on the next; but, sympa-

thizing with Emerson's opinion regarding the minds of those to whom consistency is a bugbear, he felt no need to justify either extreme, or the change from one to the other.

After some weeks' search, work was found as draftsman for the Pennsylvania Railroad at \$100 a month. "I do nothing but draw, draw, draw, all day, and haven't an extra thought to throw to a dog." It is an amusing indication of the undeveloped technical education of those times, that this ex-preacher and would-be geologist was occupied in designing a railroad station, of which he said:—"I have devised a noble Egyptian front to my depot, and will have three artists work in inventing crowds of figures for the frieze to represent in stiff Egyptian style the handicraft, commerce, steam and telegraph of modern days. It's a bright thought, and worth trouble which I shall not spare. If I can induce enough taste in the men I deal with to accept my designs, I shall introduce a new style into our Architectural Art." What became of these designs is not known: drafting was fortunately soon given up for work on coal fields.

Late in the summer (1852) Mrs. Lesley joined her husband and Philadelphia then became their residence for nearly fifty years. Although she had previously said:—"I cannot help hoping that we may end our days in New England," as they did, she was ready to follow her husband faithfully, sure of being happy anywhere he might have to go, and fervently wishing for his advance, yet more in the way of heavenly treasures than of any others, for even before marriage she had told him:—"I have never believed in your having much outward success," and in this she was in large measure right: Lesley made only one business venture, a scheme for desulphurizing coal, and that failed.

Two daughters were born to Peter and Susan in Philadelphia:—Mary, their biographer, in November, 1853; Margaret, in May, 1857. Lesley's father died in March, 1855, and this prompted the son to reflections on immortality, with a hopeful faith in an existence that should laugh at limitations of space and matter. Such thoughts fired his imagination, yet he retained a critical discrimination as to the kind of immortal glory that appealed to him. "To be glorified," is too indefinitely

suggestive: 'to be with Christ,' is too technical and limited and hierarchical: 'to live again,' contains too large a savor of the death preliminary: 'to be among the saints and angels,' expresses much and well but not all, for the harps and trumpets are not satisfactory to all"; but it all left him grieving:—"There is no one now in the world who takes the same kind of interest in us." Evidently his theological interests were not extinct; indeed just as he had thought and written upon geology while preaching in Milton, so now he read in theology—Renan, Kuenen, Stanley—while working on coal fields: but matters of still deeper concern were found in the anti-slavery movement.

Anti-slavery Opinions, 1850.—The Fugitive Slave Law, enacted in 1850, brought forth Lesley's strongest condemnation. He wrote from Milton to his father of a "theme of real horror to many here, indeed I trust to all good people everywhere, I mean of course this new and dreadful law for returning the slaves." Soon after he said in a letter to a friend:—"I had to write a sermon against the Fugitive Slave Law last Sunday, and then had to allow it to be published in the 'Liberator,' " and later to his brother:—"We are all trembling upon the eve of an eruption, over a volcano just ready to break out. I never knew such a state of public feeling, so deep, so still, so fierce, so expectant." He returned to the subject the following year:—"I am ashamed of my American birth, and more shocked than grieved to find that in *New England*, the very sanctum and last refuge of liberty, the poor fugitive is as unsafe as elsewhere." Lesley took these matters seriously, like all others, and he was courageous and fearless in the expression of his convictions. He called three of his brothers to task for living in Delaware, a slave state, and for holding pro-slavery opinions. When he was returning from a visit to Washington through Maryland and Delaware in 1850 he wrote:—"I breathe freely now that I am (almost) off this accursed slave soil, and out of that dank and damnable atmosphere," and again, "That the world can last much longer with slavery as a protected thing is inconceivable." He seems to have been outspoken on this subject as on others, for a letter from the coal regions of Pennsylvania in 1851 said:—"I have just had a scuffle with my bottle-nosed

landlord, who swears that the country will never be safe until some of these abolitionists are swung by the neck." During a visit to Milton in 1852, he wrote to his father:—"I am no fanatic in my abolitionism; but it is my life, and goes to the extremities of all my politics and religion, as all life must." For a time the modest Milton home sheltered a fugitive slave as a housemaid: after the Lesleys moved to Philadelphia effort was made to buy the housemaid's slave-daughter from her owner in the south, and sums to them considerable were spent for this object but without success. Mrs. Lesley, having mentioned their effort to Mrs. Harriet Beecher Stowe, whom she met one summer in Cambridge, wrote to her husband that if other means do not suffice, Mrs. Stowe "has a friend in New York, who has succeeded in getting off hundreds [of fugitive slaves], and who never fails. I am almost afraid to write about it, but the great reason of his success is that he is in connection with a young slaveholder at the South, who has a perfect enthusiasm for running off slaves. He is afraid to be known as an Abolitionist, has an immense property in lands and slaves, but * * * knows that his game would be up in the South were he to avow his principles."

In view of these pronounced opinions, it was natural that, as before in Milton and Boston, where the Lesleys had been closely associated with active workers in the anti-slavery cause, so now in Philadelphia their acquaintance should be largely with liberals and radicals. Among the friends made in their new home were William H. Furness, the noted Unitarian divine, Lucretia Mott, the Quaker preacher, and Robert Collyer, the Yorkshireman who, from a Methodist and blacksmith in a village near Philadelphia, became a Unitarian minister in Chicago and New York. They met Sumner before and after he was assaulted in the Senate, and they were deeply moved by the tragic fate of John Brown. But scientific fellowship was not neglected; Lesley usually attended the annual meetings of the American Association, of which he had been a member since 1849, and in which he came to know well and to be well known by the leading naturalists of the time. In 1855 he was invited by James Hall to move to Albany and take up geological work there; the reasons that led him to decline this oppor-

tunity are not stated, but one may fairly suppose that the absence of coal from the Empire State had much to do with it.

Professional Work, its Pleasures and Pains, 1852-1856.—Lesley's eminence in his profession as coal expert was gained through years of difficulty and anxiety, and though his work gave him for a time, in the '60's and '70's, a fair competence, it never brought him large means. He was much away from home in the open season. In 1853 and 1854 he made a detailed study for the Pennsylvania Railroad of a district in western Pennsylvania; the resulting map was covered with contour lines, 'a marvel of topographical labor and skill'; it is said by Lesley's nephew, B. S. Lyman, to be the first application of contours to geological mapping. In 1855 and 1856 he undertook on his own account an elaborate survey in contours of the Broad Top coal field, in which he leveled 11,000 stations; he seems to have expected large profit from this work, but it did not come. He worked actively on these surveys, 'keeping the young chainmen on the run from seven in the morning, with a scant luncheon time, until about five. Then arriving at some log cabin to spend the night, he would fling himself on the floor, exhausted, and fall asleep' till supper time. In speaking afterwards of this period, he said he had a feeling of fatigue continuously for two years. His brother, Joseph Lesley, and his wife's nephew, B. S. Lyman, were his assistants in tasks of this kind.

Work in the forested hills of the plateau country was a joy to Lesley, except at night: he had a horror of the dark against which he strove to school himself. The strongly poetic element in his nature is revealed in a letter of 1852:—"The work is interesting, the weather fine, the scenery charming. * * * After my work was over with the party, I went along the river bank, far from any house, under a lovely alley of great trees extending for a quarter of a mile. The setting sun streamed through them, and slanting over the high bank under which I walked, struck full upon the red and yellow trees that crowd up the opposite slope and were reflected, every branch and tinted leaf, in the still mirror of the water. * * * I walked till the sun was long down, and thought with much grateful feeling how work is lightened to the laboring man. I can give

you no adequate conception of the surpassing loveliness of those scenes." He again wrote rejoicingly just after his thirty-fourth birthday:—"In such a wood as this, infinitely old, interminable and immutable as it seems, a whole world in itself of ancient and natural life, the man walks beneath its canopy, in its silence and over its floor in a perpetual reverie, in converse with the beginnings and meanings of things; not questioning, for all seems right; not doubting, for all is real; not hoping, for nothing other or new seems possible; nor fearing, for it is a world at peace, in order and evidently obedient to man's slightest wish; his will is the master, in this ancestral hall."

Letters of this period show his usual extravagance in their variety of topics; they are sometimes narrative, but often include discussions of large, universal problems. His comments illustrate in an amusing manner the reverse of the change that he had noted when going six years before from Pennsylvania to Boston:—"What is it in the difference of airs in New England and in Pennsylvania," he writes, "that makes a person radical there and conservative here? * * * One reason may be that here no topic of high morality is ever mentioned. If the traveller introduces a reforming thought, it lies down in a general silence, like a gazelle fawn dropped in the snows of Nova Zembla, and is instantly frozen to death." In speaking of thanking a friend for an essay, he said:—"I am in such a desert as to literature, that I cannot find him even a cactus flower to send." He continued his interest in language studies and wrote naïvely regarding the slang word "bully" then in vogue:—"I suppose this to be the vulgar English of *belle*, as jolly is of *jolie*. I have heard it used by many vulgar people, but especially by boys, which proves its great antiquity." His earnest democratic spirit is shown in a letter to his wife:—"When I am disposed to scoff at the half-done-up look of all things in these villages, from a dining fork to a church and its preacher, and sigh for the urbanity, arts, landscapes, ruins and associations of the old world, and lament that I am not wealthy enough to take you to England and France, to live and die—I am checked and satisfied again by the same wonder which fell upon Kossuth. Here is an embryonic world, a strong man-child of the future, born of a weak mother of the

past. * * * It is a goodly land, the best for freemen, the best for future men to live in, and I will not * * * go back into the luxurious feudalism of Europe, * * * to find a happiness unworthy of the manhood of a man whose youth was spent in young America."

He often expressed his respect for laboring men, and once exclaimed in gratitude that he was not born a gentleman; years later he said:—"I hate to make my boots shine, and would be miserable in a silk hat;" yet at times he had little patience with the present representatives of the future American freemen. While on a journey in Ohio during the presidential campaign of 1856, Lesley took his place one evening at supper in a restaurant or hotel, and soon found himself, the only anti-slavery man in the room, in an earnest discussion with his neighbors at table over the recent outrage in the Senate chamber at Washington. "They justified Brooks, or rather insulted Sumner in every sentence, and I defended him with my blood at boiling point. Roars of brutal laughter rang up and down the supper room. * * * After that for an hour I had to sit in the general room, surrounded by a loathsome crew, for whom I must confess my heart wept with the saddest pity." Some time later he wrote:—"It wearies me of existence, this ubiquitous debased democracy, without culture except from newspapers, without aspirations except for some indefinable political elevation."

"Coal and its Topography," 1856.—The most important matter of this decade, geologically considered, was the appearance in 1856 of Lesley's little book, "A Manual of Coal and its Topography," in the writing of which he had had much pleasure and satisfaction. It had been in his mind for two years, for in 1854 he had sketched its contents in a letter to a friend, when he truly exclaimed:—"In fact it is time for me to write." He said to another friend, on sending a copy of the book:—"It will no doubt be read by a good many young men and some old ones, and some men of science will find it trashy because it does not tell everything. * * * I have merely organized the subject in this edition, and reserve its development for the next, for I am self-confident enough to believe there will be a next. I hope to be allowed to issue an edition

every winter, and in a few years make it somewhat worthy of its themes;" but he was diverted from this hope by other tasks; perhaps also by learning from his publishers some years later that they still had 225 copies of the little book on hand! It has long since been out of print and is now a prized rarity. The dedication of the book is a touching tribute to two of his early fellow-workers on the Pennsylvania Survey, "now in distant parts of the world, men of infinite scope and love in science, poets by Divine right, pure-hearted, true to every duty, to whom, as master in youth and friend in middle age, the author has owed what it would be presumption to attempt in words, and American science what it has never yet had the opportunity to acknowledge." The names of these fellow-workers are here omitted, for although the second remained a constant friend to Lesley till his death, the first, even though afterwards succored in illness, forfeited the title of friend by his ungrateful behavior.

It was with a glowing enthusiasm that Lesley told in these pages of the work done by the early survey, and of the superb structures which were then deciphered. One paragraph, explaining the importance of topography in Pennsylvania, has already been quoted. Others are here cited. In the Appalachians from Pennsylvania to Tennessee "we recognize a country where, from the comparative deficiency of fossils and of coal, and from the repeated and elongated outcrops of a few valuable mineral deposits, the science of geology transforms itself into the science of topography. Nowhere else on the known earth is its counterpart for richness and definiteness of geographical detail. It is the very home of the picturesque in science as in scenery. Its landscapes on the Susquehanna, on the Juniata and Potomac are unrivalled of their kind in the world." The generalizations then formed "were so vast that to our eyes, familiar with rock curves ten and twenty miles in radius, underground or in the air, all that customary European local research which filled the proceedings of societies in lieu of new and larger matter seemed tedious and puerile. * * * Years of patient toil it cost us to unfold the mysteries of the Pennsylvanian and Virginian range—a tangled hank, to be untangled thread by thread and rearranged skein by skein—a

tracery more elaborate and intricate than Gothic or Arabesque—nature's primeval labyrinth, in which the minotaur was but a form of science cast in metal and sculptured in stone; a sphynx whose riddle has at length been read and written out by men like Henderson and Whelpley in what are now to be forever the hieroglyphics of geology. Their magnificent maps, executed under singular difficulties * * * have disappeared, but can never be forgotten."

Henderson's map of the Juniata district is described as "a *chef-d'œuvre* of geological acumen and constructive genius in field work, impossible to excel, and which, under any other organization of the Pennsylvania State Survey, would have made the name of him to whom we owe it, fifteen years ago, familiar to every scientific ear in Europe." He justly exclaims over the plunging anticlines of the Seven Mountains:—"This magnificent group of zigzags (studied out by Mr. Alex. McKinley) has probably no rival yet known upon the surface of the earth." This may seem unwarranted exaggeration to readers not acquainted with the Alleghenies of central Pennsylvania, but not so to appreciative students of that extraordinary district. Upon this point we may quote Sir Archibald Geikie, who wrote:—"Those who have travelled through the Carboniferous region of Pennsylvania, or have studied the excellent detailed maps of it which the State Surveys have published, will not wonder at the claim made by Lesley that 'topographical geology was born' in that State; nor will they fail to note how easily and irresistibly Lesley was led into that domain of geology where he became so pre-eminent a master. The contours of the surface depend so directly and clearly upon curvature and fracture of the terrestrial crust on the one hand, and upon the results of erosion on the other, that in few tracts of the earth's surface is this relationship so readily grasped, or appeals so powerfully to the imagination." (Quart. Journ. Geol. Soc., lx, 1904, xlix-lv.) Fine examples of ridges and valleys produced by the erosion of folded strata of unequal hardness have, since that earlier time, been mapped in north-western India and in Algiers, but the landscapes of Pennsylvania are unrivalled still because of the occurrence there of three dominating sandstones in a great thickness of inter-

mediate weaker formations, the whole having been compressed into a remarkably systematic series of folds with gently pitching axes, and worn down during successive cycles of erosion into more extraordinary groups of zigzags than any others in the geologically known world.

Catastrophic Views, 1856.—Lesley's knowledge regarding the folded structure of the stratified Appalachians was minute, extensive and accurate. As to the origin of the folded structure, he doubted Rogers' explanation by huge earthquake waves, and preferred Elie de Beaumont's theory of lateral pressure. His knowledge of Appalachian topography and of the relation of form to structure was exceptionally full; but his theory regarding the demolition of the initially upfolded anticlines and the origin of the existing forms was fantastic; for he here followed Rogers' catastrophic ideas, to which he was perhaps inclined by his belief in the rapid supernatural processes that were associated with his early theological views. He maintained that Appalachian erosion had been performed by a vast ocean flood, rushing southward from the Arctic Ocean, and that the flood worked "with infinite force and speed, and ceased forever." He was very positive in the matter. For the field-worker, "the rush of an ocean over a continent * * * leads off the whole procession of his facts and is indispensable to the exercise of his sagacity at every turn." The evidence adduced in favor of this view is naturally inconclusive today:—"The crests of these mountains are more or less torn up, and notched or gaped according to their local exposure to the denuding agency; and the facts coming under this head are of themselves sufficient to prove that it could have been no other than a fluid, a vast body of water moving vehemently across the suffering edges of the strata. * * *

The curved points and cones of Appalachian valleys are, therefore, so many monuments of sea currents moving over its surface while submerged, or of a deluge poured across it after it had risen into the air." The location of the Delaware wind gap, a half-depth notch in Kittatinny Mountain of northeastern Pennsylvania, "is at a shoulder where the rush of a super-continental deluge would be at a maximum. It furnishes an unanswerable proof that no water now running made a gap;

in other words, it proves the cataclysmic origin of every mountain gorge in the land."

Soil-creep, 1856.—The attribution of so much work to a catastrophic flood was singular, in view of Lesley's clear recognition of the phenomenon now known as soil-creep, regarding which he wrote in the "Manual":—"The whole surface of all hills has been in slow but perpetual movement downward from the beginning;" he illustrated this important process by an excellent figure (p. 36) of the dragged soil on hillsides, a matter that was doubtless familiar to many of the boys who in those days collected minerals in the quarries around Philadelphia. It is now understood that the slow creep of soil has much to do with the demolition of mountains and with the development of subdued forms in the later stages of their degradation. Lesley, with his explicit text and expressive figure, was among the earliest observers to make clear statement of this process, though he is not mentioned in Göttinger's elaborate study of this simple phenomenon (*Beiträge zur Entstehung der Berg-rückenformen. Penck's Geogr. Abhandl., ix, 1907*). Nevertheless in 1856 Lesley left little work for soil-creep to perform in his catastrophic explanation of Appalachian topography; but ten years later his views were modernized.

Lesley as a Draftsman.—The illustrations in "Coal and its Topography" are admirable. They were all carefully drawn on wood by Lesley himself, and, as he was a good draftsman, their lines express his meaning just as accurately as do the well-chosen words of his text. Many small cross-sections exhibit the close relation of structure and form which is so striking a feature of Pennsylvanian landscapes and which in 1856 was not a generally understood subject. The maps are even more valuable; they were expressively drawn in sketched contours, and brought out clearly for the first time the singular zigzag patterns of the Allegheny ridges and their dependent foothills. Lesley disliked hachures; they make "a hateful caterpillar-like topography, unnatural ranges of supposititious mountains, crawling hither and thither over the paper, not only teaching nothing, but suggesting falsehoods at every step. A few delicate contour lines would not only avoid all this, but would show what is actually known." This is too wholesale a

condemnation; it applies only to badly drawn hachures, for when hachures are well drawn they may be superior to contours in representing certain forms, such as low terraces in a sloping valley; contours, on the other hand, are superior to hachures in setting forth the long ridges of the Alleghanies; and it was in sketched contours that Lesley later prepared an admirable outline map of Pennsylvania, on which its remarkable features are strikingly shown.

Would that the above citations might lead American geologists and geographers to read Lesley's admirable little book and to carry it, along with his "Volume X" of the Second Survey, with them into the Susquehanna and Juniata districts, where they might see for themselves the marvels of structure and of form which Lesley so well describes, and which earth-students today too generally pass by for newer and less extraordinary fields! Would that visiting Europeans might at least pass through Pennsylvania by daylight with Lesley's books in hand—they could borrow them from a friend—and thus recognize the field in which great lessons were learned; better still if they would pause more than a day in the Alleghanies before too hastily pressing on to the novel West.

Personal Opinions, 1850-1863.—The same year in which "Coal and its Topography" appeared, Lesley was appointed Secretary of the Ironmasters Association, later called the American Iron Association, at a moderate salary; thus his attention was directed to ore beds and iron furnaces, as well as to coal fields and mines. He thereupon, from having previously advocated free trade on abstract principles, became heartily devoted to protecting iron on grounds of immediate practical expediency, and spent some time in Washington lobbying for a tariff bill. "I have been at it for a month," he writes, "erecting paper fortifications, tabulated bastions, formulistic curtains, newspaper articles for redoubts and covered ways, bomb proofs in the shape of private correspondence, and mines under the pamphlet lines of the enemy * * * I am pledged to protection, odd as it may seem; and all because I see that the prosperity of the country at a thousand points is half-involved in the success of innumerable furnaces, founderies, forges and rolling mills, scattered all over a dozen states, and

feeding half a million people, besides giving point and spirit to their intelligence and energy." He was called to task for this by a New England correspondent, and replied:—"The 'excellence of free trade' is a general law, including apparent exceptions, as every real current involves eddies. To offer a fictitious free trade in iron, is to ruin our iron-works, and give the English nobility a monopoly of the manufacture." The English nobility seem at no time to have inspired the regard of this ardent American!

The hard times of 1857 left Lesley for a time without work and without salary. He wrote fifty letters to secure engagements for lectures; they were all answered, and not one with encouragement; he was compelled to sell some of his few investments at a heavy loss to carry his family through the crisis. His wife made her sacrifice by taking boarders. Even in the following year it was a "hard scrabble with him to provide the bare necessities of life." He notes that he "went to see the Ravels [pantomimists]; the first quarter of a dollar I have dared spend in pleasure for a month." When he again secured field work the discomforts of travel troubled him:—"I write in a roofed desert called in America a Hotel—acres long and deep, without a comfort or a picture, or a reminiscence, in all its hundred rooms." When he stopped in the country he found the "houses are uncomfortable, roads vile, people rough but good natured, beds short and soft, bread hot and doughy, churches few and intermittent." On one occasion he casually states:—"We were obliged by a smash-up * * * to walk out five miles * * * and thereby had a chance to see a fight between a mob of negroes and three kidnappers." He was not favorably impressed with the new country on the way to St. Louis (1861):—"A wide flat desert, ornamented with occasional shanties, and not half of it yet cleared of its timber, stretches from the Beaver river in Pennsylvania to the Mississippi—a land of horror and silence to the poet and historian: a land of brutality now—what it is to be God knows, not I. * * *

The utter cheerlessness and loneliness of this journey exceed all I ever experienced."

The extract already quoted about "a goodly land, the best for freemen," expresses Lesley's usual opinion about our coun-

try much better than this pessimistic view of the stretch from Ohio to Illinois, which may have been only a temporary misjudgment occasioned by personal discomfort; or perhaps it should be classed with a number of opinions that are found scattered through his letters, but not borne out by later events, for in many matters Lesley was not a prophet. Thus when his church affairs in Milton were approaching a crisis in 1848, he said, regarding certain critical difficulties:—"I have nothing to do with them. Nor do I think they will materially affect my plans;" yet the turn that the affairs soon took practically decided him to give up the ministry in Massachusetts and to take up geology in Pennsylvania. Again, in the midst of the acquaintance that he so greatly enjoyed with leaders of liberal thought in Boston, he wrote in 1848:—"Unitarianism * * * has done its work and had its day and is drying up and vanishing;" and two years later:—"I never come into close contact with Unitarians, but I am chilled and repelled;" yet he long prized the friendships of those earlier years, he occasionally preached in Unitarian churches, and a quarter century after leaving New England he saw with whole-hearted sympathy and satisfaction the vigorous growth of Unitarianism in Philadelphia; although he did not formally join that denomination, he frequently attended its religious services, and in 1884 he described himself to Dr. McCosh, president of Princeton University, as an "apostate Presbyterian." His close approach to Unitarianism may be judged by the following extract:—"What is Christianity but the enforcement of two or three ideas—that the Creator is incapable of imagining a hell—that Jesus may be imitated—that every man has as much right to all good things as I have—that the soul ought to be stronger than the body—that nothing but virtue is indispensable—that the more one loves the richer one becomes."

He wrote regarding American affairs in 1849:—"There may be a short collision between the infatuated South and the indifferent North;" and he thought with many another in 1861:—"The southern army must melt away, like snow before the sun's advance." He disliked the South while slavery lasted, but in 1871 he wrote from Norfolk:—"I love the backwardness of the South. It rests one who is weary with the

driving 'progress' of the North. So far as I can see, mankind scarcely better themselves with all their boasted railways, factories and forcing schools." After his conversion to the doctrine of protection, he said in 1857:—"Protection first, and free trade follows inevitably. * * * Let our iron works be protected five years longer, and no one will ask for a tariff;" yet he remained a protectionist all his life, and iron is still protected years after his death. During a summer in Europe, in 1863, his opinion was that "France is a *great* country; far greater than the United States. * * * And all Europe owns that France is mistress of Europe. She rules the world. * * * There is no unity possible for Germany. *Never* will Germany be a nation, *Never*. * * * Little Denmark pulls Germany's great nose with impunity." He compared French and German theaters: the first, "all tasty and trim, elegant diction, neat wit, courteous audience"; the second, "all dirty and crowded and gaudy, tawdry, fustian, brutal and coarse." Some years later, during the Franco-Prussian War, he wrote:—"Everybody has an instinctive belief in German veracity, probity, steadfastness and valor. * * * The French are so ignorant, illiterate, and ill-informed about the rest of Europe, that they must overrate their own strength."

The American Philosophical Society.—The American Philosophical Society in Philadelphia, founded by Franklin, and the oldest learned society in the United States, was fortunate in appointing Lesley, in 1858, at a moderate salary to the position of librarian, a post that he held with profit to the society and with much satisfaction to himself for twenty-six years. A little later he became one of its secretaries, and held this office until 1887, when he was elected a vice-president; in this position he continued for ten years and then declined re-election. As librarian he undertook to make a card catalogue of the valuable collection of books, a work in which he was later aided by his wife and his elder daughter; thus he spent many busy but tranquil hours in the quiet old rooms of the society on Independence Square. As secretary he was in charge of the society's publications for a considerable period; he contributed to them about sixty-five papers, and was a regular attendant at the meetings, where he was a frequent speaker.

The Iron Manufacturers' Guide, 1858.—As secretary to the American Iron Association, a position which he held till 1864, he published in 1858 the "Iron Manufacturers' Guide," a large octavo volume of nearly 800 pages. Brief notices of many iron works occupy one-third of the book, and a careful discussion of the geological occurrence of iron ores fills about half of the remainder. The collection of the material for the book, a task in which the author had two young assistants, required much travel over Pennsylvania and other states on visits to ore beds and iron furnaces. The most personal feature of this compendium is the preface, in which the author expressed in an outburst of unrestrained indignation, his opinion of his former chief, H. D. Rogers, for the manner in which the work of the assistants of the State Survey, twenty years before, had been ignored in the final report, which after long delay was published in Edinburgh in 1858, while Rogers was professor of natural history at the University of Glasgow. There was truly much ground for indignation; for on the geological map of the state, "constructed from original surveys * * * under the superintendence of Henry D. Rogers, State geologist," the name of Lesley, who had so laboriously compiled and so carefully drawn and colored the original map ten years before, did not appear, and even in the preface to the first volume of text, where the preparation of the map is discussed at some length, Lesley is not mentioned in connection with it. But the outburst does not seem to have brought much relief. Lesley "suffered a great deal silently, about the awful business. It is no joke to be compelled to witness for the truth," and his wife "felt very uncertain about the wisdom and expedience of Peter's preface:" yet even the "sweet and gentle" Lesquereux wrote that what Lesley said was less than the truth; indeed others besides these two had found the director of the first survey a hard taskmaster, more interested in Pennsylvania and in himself than in his assistants.

It seems that a general acknowledgment of the work of his assistants in the preface to the first volume of the Final Report had satisfied Rogers, who there wrote:—"For full mention of the special parts performed by the individual members of the corps in the various successive stages of the Survey, I beg to

refer to the widely circulated Annual Reports of its progress. To attempt the precise history of the labors of each, in a field where their duties were so multifarious, would, besides being somewhat invidious, lead me into too minute and tedious a narrative." Lesley felt differently; he characterized the Final Report as "the most brilliant imposture and the most extensive scientific theft of the present age." The assistant, who had years before drawn the map, was naturally exasperated to find that "his own name has been erased from the map of Pennsylvania which he alone constructed and compiled, from the thirteen great sections across the State, the very style of which he was obliged to invent, from all the vertical sections of the coal measures which he was the first to propose and alone executed, from the hundreds of illustrations of the geology of the State which he re-drew. * * * And to add insult to injury, his name is attached * * * to the map of the Anthracite Coal region with which he had nothing whatever to do, never having seen it until it was published." But it was not only Lesley's work that was thus submerged; Whelpley, Henderson, and McKinley, on whose original field work Rogers' results were based, were like the map-draftsman named only in the preface and not at all in the text. Lesley resolved to make amends for such neglect; hence in the numerous extracts from the Final Report which were presented in the "Iron Manufacturers' Guide," "in all cases where the memory of the writer would serve him, the authority quoted was that of the geologist who did the work, invented the illustration, dared the conjecture, gave the explanation—and not that of the geologist who after the survey had been launched like a ship from the stocks would have wrecked it on every reef but for the ability of its crew, and who has, now that it is at last come into port, appropriated all the cargo."

A later Estimate of Rogers, 1876.—Rather than quote further from these violent expressions, the more temperate statements of twenty years' later may be at once introduced; for there Lesley almost returned to the high estimate of Rogers that he had earlier held. At the time of apprenticeship on the First Survey, he was only a young fellow of twenty, full of enthusiasm for his leader; he was a striving man of nearly forty

when he excitedly wrote the preface to the Iron Manufacturers' Guide; he had gained secure position and was well towards sixty when, as State Geologist of the Second Survey of Pennsylvania, his deliberate judgment was calmly stated; for he then wrote that Rogers "had always shared with his old assistants the two prime elements of a successful scientific career: love of geology as a science, and personal ambition as a geologist. In their case the first greatly predominated over the second. With him the two were more equally balanced. * * * The delay [in publication of the First Report] had indeed benefited him in this respect, that it left him to stand alone in the sunshine of this great work; for most of his assistants had dispersed to seek avocations of a different kind, and none of their contributions to * * * Appalachian geology had appeared, or now could ever appear over their own names, or redound to their credit. But for the long delay of such publication the Legislature was alone to blame. * * * Let any one read the special memoirs with which he [Rogers] closes the second volume of the Final Report, and there can be no sentiment but one of admiration for the breadth of his views, and the clearness, force and elegance of his delineations" (Second Geol. Survey Penn., Vol. A, 1876, 122, 127).

Personal Items, 1862-1863.—The period following the publication of the "Iron Manufacturers' Guide" was one of increasing professional activity, which resulted in making Lesley the most noted coal expert of his time. His competence was unquestioned and his honesty was unimpeachable; his services were constantly in demand. His work soon extended far outside of Pennsylvania. He was called to Montreal in 1862 to discuss Taconic problems with Dawson, Logan and Hunt, and while there "had a glimpse of the English nobility; it is on the whole no more attractive than the professional, the mercantile, or the mechanic worlds." He was sent to examine coal beds and iron ores all along the Appalachians, from the British provinces in the northeast to Tennessee on the southwest: he was so hard pressed with work that he said he was like a ship "carrying studding-sails in a gale, and every spar creaks." Many of his reports contained matter of scientific importance in addition to their technical details. Some of his professional studies

were published in scientific journals, his "Section of Coal Measures on the Cape Breton Coast" (*Proc. Amer. Phil. Soc.*, ix, 1865, 93-109, 167-170) being a good example of this kind.

Small wonder that the little coterie of five or six men, who gathered in Washington in 1863 and took upon themselves the selection of the fifty incorporators of the National Academy of Sciences should have included Lesley's name in the list. His wife writes of his gratification on receiving the official invitation:—"This was a very great surprise to Peter, a thing entirely unsought and unsolicited, and gives him pleasure," but she adds:—"He says he is quite mortified at himself, that he can be so tickled with a straw." His account of the first meeting, held in New York in March, 1883, is amusing in its revelation of certain discussions regarding which, by general consent, no record was to be made in the secretary's minutes. The following summer, when Lesley was in London, he was invited to attend a dinner of the Royal Society Club, where he gave an account of the formation of our National Academy, "upon which great laughter arose" among his gracious hosts, perhaps because it seemed to them so absurd that a scientific academy should be founded in a raw wilderness: however, a member of the Royal Society came fifty years later as an invited guest when our Academy observed its semi-centennial celebration in 1913, and seemed at that time to value his election as one of our foreign associates.

In the meantime Lesley's other interests were as active as ever. Just as he had been intensely moved by the fate of John Brown, so he was alternately excited and depressed by the fluctuating struggle in the War of the Rebellion. He was still vehement in his likes and dislikes, extravagant in praise and violent in condemnation. He found restful entertainment in the theater, and greatly enjoyed the weekly gatherings of scientific and literary men in Philadelphia, first brought together by Dr. John Frazer, later by Fairman Rogers. He continued to be an active reader of many books, and he thought very seriously, in 1859, of undertaking the publication of a "half-scientific, half-literary weekly * * * devoted to geology. It seems to be wanted and must soon be had; the space is vacant and I am the man for it; it only requires energy to start it, to

make it go. I should like to devote the residue of my mortal career to establish such a magazine of science here as should last after I had gone." He was constantly drawn aside from geology by the breadth of his sympathies and interests; thus in the history of the Lehigh valley he found "superabundant materials for an admirable romance," such as he had long had in mind to write. "How beautifully a year might be spent at such a romance, which might blend the sweetest love scenes, and the wildest adventure, with the most enduring and varied religious enthusiasm." At about the same time he exclaimed:—"I long earnestly to preach in New England. * * * I would jump for joy at a fairly involuntary 'Call.'" He recognized the distraction due to his versatility and said:—"It seems to me strange that I cannot settle to one vocation like other men."

In the latter part of 1863 Lesley went to Europe to examine for the Pennsylvania Railroad the method of making rails and the then new Bessemer process of producing steel; and thus had occasion to visit many furnaces and mills as far as Austria, as well as to meet many men of science. On the steamer he met Sir Henry and Lady Holland, who entertained him in London; on hearing of this his wife was in a panic at home, fearing for his social mishaps. He noted that "the anxiety of the English to make the impression that they are quite impartial and just [regarding the North and South] shows a conscience ill at ease." He met Percy, the metallurgist, Owen, Darwin, and Hooker; Ramsay, Murchison, Selwyn, and Lyell; at the house of the latter he played "blind postman" at a boy's birthday party, and enjoyed seeing "funny old Sir Charles, with a handkerchief round his head, dancing about to catch us." On crossing to France he saw Elie de Beaumont, Verneuil, Delesse, Gaudry, and Mortillet in Paris. He visited St. Etienne and found it "as mean and dirty as Pottsville." He went to Abbeville to see Boucher de Perthes, and was as much interested in the relics of ancient man as in iron manufacture. On reaching Germany he was impressed with the contrast between French taste and German roughness. He looked up his old friends at Halle, and on passing through the Porta Westphalica, noted that the Weser "breaks through a ridge like our Sharp or Blue mountains." Returning to London in January, 1864,

he dined as chief guest with the Geological Society Club, of which Ramsay was then president, with Forbes, Murchison, Selwyn, Lyell, Bigsby, and Falconer at table.

Lowell Institute Lectures, 1865, 1866.—During the summer of 1865 and the following winter, Lesley greatly enjoyed his visits to Boston when preparing and delivering a course of lectures at the Lowell Institute. He had written seven years before regarding New England:—"I live the year round in the hope of a week there," and a few years later had described that corner of our country as "the land of energy and fidelity, the land of piety and charity, the blessing of the earth, from which streams of intelligence and high-mindedness have gone forth to make green the West." The subject of his lectures was not geological, as one might have expected it to be, but a matter of even larger interest, namely, "Man's Origin and Destiny," and he treated it as only a man of his erudition and temperament could. He was "terribly frightened" on beginning the first lecture, but "got through just within the limits of the hour, by hurrying the last three pages. * * * It was a very nice audience,—consisting chiefly of men. But there were a few women knitting." His hearers were flatteringly attentive: "you would hear a pin drop from the beginning to the end," and their quality led him to say:—"I couldn't get such an audience anywhere else in the United States," but he was vexed once when his hearers laughed at the wrong place. His lectures overran the usual number of twelve, and the course was extended by two more. Of the last lecture, he wrote:—"I gave the audience my Arkism. They were as patient as lambs under the infliction." When it was proposed by a friend that he should repeat the lectures in Philadelphia, he wrote to his wife:—"I assure you, my love, we can't get up an audience for them in Philadelphia which will hold together six nights. There was never got together in Philadelphia such an audience as I had last Wednesday evening here in Boston."

One of the pleasant features of this Boston episode was the freedom of mind that came from having but one thing to attend to; another was the great enjoyment that Lesley had from the men he met there. He did not see so much of his relatives and old neighbors, for he was in the hands of a new set. He

had a charming little breakfast with some friends, "only the people keep me talking, talking, and I can't get enough to satisfy my hunger." He describes a meeting of the American Academy at Theodore Lyman's, when five members read papers, as an uncommonly rich evening; he couldn't sleep after it and read till four in the morning. He was invited by Dr. B. A. Gould to go to a "Warren party," later known as the "Thursday Evening Club," and said that it "has impressed upon the educated merchants' class of Boston a love for * * * science, not as means, but as end, such as none of our machinery in Philadelphia is capable of stamping." He had the pleasure of dining at Shady Hill, Charles Eliot Norton's residence in Cambridge, where he walked one evening in the snow. "What a grand old place it is! What a splendid library parlor it is! * * * Soon came Dr. Palfrey, Longfellow, Gray, Lovering, Jeffries Wyman, C. [W.] Eliot, C. Wright, and somebody else who knew me very well, but I couldn't make him out. My evening was charming in every respect." He exclaims:—"What an ocean of life breaks on these rocks of Boston society! * * * It is heaven upon earth here, with nothing to do but read, and talk, and think." Everything satisfied him, when viewed under these favorable conditions:—"Such a wife! such children! such friends! * * * such a nice science to work in and for! such an age to be born in! such a Country to call one's own!"

Man's Origin and Destiny.—Just as the "Manual of Coal and its Topography" exhibited Lesley at his best as a landscape artist in the description of the ridges and valleys of Pennsylvania, so the book embodying his Lowell Institute lectures exhibits most completely his other side, as a wide reader and an adventurous thinker in all the sciences. The preface describes the book as "merely a series of familiar conversations upon the current topics of interest in the scientific world * * * a general sketch of the present bearings of science upon the vexed question of the origin and earliest history of man. * * * Views are stated, therefore, in round terms. Nothing is closely reasoned out. Much is left to the logical instinct, and more to the literary education of the reader." The lectures were originally written in the summer of 1865 at a dis-

tance from the author's notes and library; hence the paucity of references to sources; but the subject was so rich and the writer's memory was so well stored that each lecture overran its time and was read only in part, for the rules of the Lowell Institute judiciously hold the audience only an hour, however long the lecture may be. The treatment of the subject was extraordinarily free and discursive in the way of introducing instances and illustrations from an endless variety of sources, and delightfully compelling in its unhesitatingly assertive style; no wonder the audience sat entranced; and besides this, those who knew the man will understand that the lectures were delivered with an absorbed enthusiasm, sufficient to hold the attention of any audience to any theme. It may not be easy to see just how some of the freely introduced incidents bear on the problem under consideration, but they are interesting all the same, as a few examples will show. The sixth lecture on the early social life of man contains the following story:—"No race has ever yet consented to work for nothing cheerfully. All the sense of justice man has comes from resistance to that attempt. If the reconstruction of Southern society is to be a success, it can be so only on condition that the white man share the soil, the shop, the schoolroom and the forum with the black. * * * To show you how delicate a test of justice work can be, I will tell you a story, which a friend of mine, an engineer upon a Southern railroad, told to me. A railroad was projected through the swamp-lands of Florida. Slaves were hired from the planters of Georgia to do the work. A day's task for every man was measured with a ten-foot pole. The slaves rose early and by working diligently could complete their tale of work by two or three o'clock, and have the rest of the day for their amusement. * * * The avaricious contractors made new poles, 13 inches instead of 12 to the foot. The day's task was unaccountably lengthened by an hour or more. The blacks could offer no explanation, and made no resistance, for the work was still within the range of cheerful diligence. Another month passed by and a third set of poles were distributed. The foot had now become 14 inches long, and the day's task lasted until sunset. The defrauded labourers, seeing that there was no use struggling with an

unjust despotism, returned to planation-habits, shirked all the work they could, lost heart, and fell back into that barbarism, the essence of which consists in giving up the soul a prey to the forces of nature."

Similarly the eighth lecture, on the origin of architecture, tells of a visit to the roof of the Sainte Chapelle in Paris in company with the architect in charge of its restoration:—"I occupied myself with the bits of carving which surround the pinnacles of the buttresses, and which are entirely invisible to persons in the street—hundreds of leaves and flowers, and delicate morsels of fretwork, which no eye had seen for centuries, even since the stone-cutters had hoisted the blocks unchiselled to their places, and yet as nicely wrought as if they were intended for the doorway of the porch. And I could not help asking myself the question, When will our architects get such a conscience as those old masons had? And I wondered also when the time would come for a public taste impatient of our meretricious sham shop-fronts on Chestnut-street or Broadway, showing their ragged edges and unfinished cornice-ends, and soft brick side walls, up and down the street as shamelessly as harlots in the evening flaunt their tawdry." But the body of the discourses is made up of scientific matter, on such subjects as the anatomy of apes and of man, the conditions of primitive life revealed by the Swiss lake dwellings, the lessons of Egyptian architecture, the origin of the alphabet, and the structure of language.

The lectures were published (1868, 2d ed., 1881) and found to be suggestive and stimulating by many readers: Lesley's own comment upon them is judicious:—"It is very encouraging, I confess, to get *hearty* commendations from competent judges; and yet I can't help entertaining and acting upon the conviction that no one is so good a judge of one's mistakes and one's leanness as one's own self. I am extremely dissatisfied with these performances. They treat the subjects concerned with an appearance of profundity, but real superficiality. They are the result of years of reading and reflection; yet are after all mere outline sketches."

Lesley as a Philologist.—One reason for Lesley's unusual breadth of information as shown in his lectures was his ac-

quaintance with many languages. He had already as a boy made a beginning with four languages—Latin, Greek, French and German. He tells, in 1889, that he found a fresh world for study in comparative philology while he was at Princeton nearly fifty years earlier: "How I dashed at Arabic, Armenian, Coptic, Persian, Sanskrit, as if I were at a football play! Then I went back to Greek and Latin with wide-opened eyes. When I had German as a vernacular I played with Danish, Swedish, Icelandic. * * * I devoured Welsh, Erse and Gaelic. * * * I spent months over the Basque and Zingari; got Hindu and Tamil lexicons and New Testaments. * * * I made comparative lexicons of the Polynesian dialects. I * * * plunged neck-deep into the Mandarin dialect, and then compared the Corean, Japanese and Malay. All this brought me back to my Hebrew studies, until at last I found myself like an ass tethered comfortably and permanently between the haystacks of Hebrew and Egyptian, where I have peaceably and pleasantly been munching and munching ever since." How far his etymological comparisons were safely grounded may be left to the determination of other philologists; but there can be no question that his conversational accounts of the derivation of words, as well as his lectures on this difficult subject, were fascinatingly interesting to many hearers.

"Five Types of Earth Surface," 1866.—It was during the period of Lesley's most active professional engagements on practical problems that he paused long enough to write, in explanation of some work that he had done, an article the scientific importance of which has not been generally enough recognized. He had attempted, as a result of a study prompted by T. E. Blackwell, managing director of the Grand Trunk Railway in Canada, to make a map of the "whole country" on which topographic form would be interpreted by its relation to geological structure; and he selected for publication a section of the map stretching from Cincinnati in its northwest corner southeastward beyond Raleigh, N. C., the accompanying article being entitled:—"Notes on a map intended to illustrate five types of earth-surface in the United States, between Cincinnati and the Atlantic seaboard" (Trans. Amer. Phil. Soc., xiii, 1866, 305-312).

The article is not only of value topographically, but it is of special interest because it was here that Lesley frankly announced his abandonment of the catastrophic theory of erosion. In describing his original map, he said its charm "lay in its unmistakable utterances respecting different topographical types of earth-surface or strongly contrasted systems of erosion, lying in masses, side by side, or running for long distances in parallel belts." He called especial attention to "the great Cumberland-Allegheny-Catskill plateau, with its horizontal geology and its quaquaversal, arborescent drainage-system, boldly contrasting with the Appalachian topography in front of it" as "settling the questions of mode and agency in favor of slow subaerial denudation. * * * The old cataclysmic doctrines cannot be upheld in the light of our present geological knowledge. Erosion by wind and rain, sunshine and frost, slow chemical solution, and spring and fall freshets, has done the whole work. * * * I must now abandon wholly the idea to which I clung, with slowly relaxing grasp, so many years, that a complete erosion theory demanded some such forces as would have been supplied by the extra efficiency of an ocean translated across the upheaved surface through the air." Thus Lesley became a uniformitarian. It may be here noted that when Powell's report on the "Colorado River of the West" appeared about ten years later, a visitor, seeing it on Lesley's table, asked how Powell's ideas on erosion affected the problem of Appalachian topography; to which the author of "Coal and its Topography" replied:—"I used to think I knew all about erosion; but I was all wrong; didn't know anything about it at all." It is interesting to add that, as a dweller on the margin of the glaciated area, Lesley naturally concluded that "ice had no hand in Appalachian erosion. All it has done has been done in the north, and its only action was to polish a surface already made."

The published map of the "five types" showed "what we have a right to expect when the United States, at peace once more among themselves, and free from the curse of slavery, thank God, shall take up in earnest the work of studying and expressing to the eye the character of the countries which they possess in common." It is singular, in view of this opinion,

that Lesley did not give more attention, when he became director of the Second Geological Survey of Pennsylvania, eight years later, to securing a good topographical base for his county maps; but he had at least, in his later years, the pleasure of seeing a beginning of the realization, in the topographical maps of the United States Geological Survey, of what he had said we had a right to expect; just as Loomis had at a somewhat earlier time the satisfaction of seeing in the tri-daily weather maps of the "Signal Service"—now the Weather Bureau—the actual attainment of what he had hoped for as a dream some twenty years before.

Two Years Abroad.—Whether from Boston excitement or from Philadelphia overwork, Lesley fell ill in the spring of 1866, and in the autumn of that year went abroad with his wife for a long absence, until May, 1868. Mrs. Lesley spent the first winter in Paris, while Lesley traveled in Spain and Italy. His letters reveal a whirl of changing thoughts, with abundant superlatives, and more attention to history, art and architecture than to geology, thus disclosing a side of his nature worth recording. Between Genoa and Leghorn he enjoyed meeting a mixed lot of commercial travelers, regarding whom his pen seems to have taken the ink into its own nibs and let it run away, for he says his companions were "the best company in the world, educated, polite, polished, witty, full of fun, knowing everything, yet not pretentious nor obtrusive, and evidently honest and high-minded. * * * Any one of them is worth twenty times his weight in English 'gentlemen,' and a hundred-fold his weight in English 'officers', who are brutal, ignorant, conceited, afraid of everybody and dissatisfied with everything, unable to protect themselves and ready to bully the world."

In Florence he recalls the centuries of violence and fraud in the Middle Ages; in Rome, he would rather have built the baths of Caracalla than St. Peters, and says that if he had come as far as Rome in 1845, no power on earth would have prevailed to prevent him from becoming a sculptor—instead of a colporteur. He is surprised that Rome does not awaken a single Christian sentiment in his soul, and thinks, as others have, that it is because the sights there are so essentially pagan. In Naples he pities the "sweltering mass of human beings,

packed into narrower, darker, filthier quarters than in any city this side of Edinburgh, * * * how blessed is our lot across the water!" At Sorrento, he relaxes completely and becomes "utterly indifferent * * * to all the ordinary topics of physical inquiry." He wrote:—"I live in this sensuous absorption of the visible. * * * As for causes and methods of production, I feel no interest in them any more. I know that these rocks are Oolite—but they might just as well be Silurian, for all I care. I see that anticlinals cross the peninsula [a daring generalization], * * * but I feel no desire to make a study of its topography." This is not a revulsion of feeling due to illness, but holiday exuberance caused by convalescence and recovery, for in a letter to his wife, who was spending the winter alone in Pau amid somewhat uncongenial surroundings, he exclaims:—"I feel so well when I get up! I eat such huge breakfasts! I am ready for anything! And I am so funny all the time!! I keep the breakfast and dinner table in a roar. I am so excessively witty!!! I say so many hundreds of good things! You wouldn't know your stupid old Peter." In Venice, he explains his theory that the name comes "not from the Veneti, but from Venus; and that the Doge's palace represents an ark floating upon the water, the waves of which are symbolized in its arches;" in Milan, he spends hours in the Cathedral, where he says of the vast number of piers, "the Allegheny forest is not more imposing." Unhappily the benefit of the Italian winter did not last; he fell ill again on the way northward, and reached France in the spring little better than when he had gone south the autumn before.

He passed some uncomfortable months in Paris as Commissioner to the Exposition of 1867, and then went to Switzerland, where Mrs. Lesley spent the summer at Vevey more pleasantly than the previous winter at Pau, while Lesley roamed about. One of the most notable events of this period was his visit to Combe Varin in the Jura to see Desor, for whom he felt a strong affection. He writes that on his way there, in July, 1867, "I addressed in French a young man, to know if he could put me upon the foot-path up the cliffs. * * * In honest American English he replied—'Why I know you; you are Professor Lesley.' 'And you,' I asked. 'I am Mr. Shaler, of

Cambridge. I am studying the Jura.' 'Come up with me then, to see Desor,' I said. 'I will,' he replied; 'Agassiz told me I must see Desor.' Shaler was with a young English geologist who knew the Jura strata and their fossils, and all three went up the cliff together. "What a charming time we had! I became a humble scholar, and they taught me Velangian and Neocomian * * * and gave me fossils, which my old bleared eyes [he was then 48] could no longer detect." On reaching Desor's chalet, hid behind a little ridge and commanding a glorious mountain basin, they had jolly times. The approach was through an avenue bordered with tall trees, on which the names of many distinguished visitors were carved. Lesley's tree had quivering leaves, which seemed 'appropriate to his sensitive and alert nature.' A class of young men came for a lesson. Desor "expounded the distinction between *vallon* and *vallée*, *cluse* and *combe*, showed the order of the rocks, * * * and the structure of the region."

In the autumn of 1867 a delightful opportunity was opened by an invitation from Miss Lucretia Hale of Boston, an intimate schoolday friend of Mrs. Lesley, and her brother, Charles, who was on his way to Cairo as American Consul General, to spend the winter with them in Egypt and make a month's trip up the Nile in one of the Viceroy's steam yachts. The party crossed from Marseilles to Alexandria by steamer, where among the passengers was Mariette Bey, whose works in Egypt Lesley had carefully studied; Daniele Camboni, an apostolic missionary to central Africa, who knew all the great African travelers; and also a traveler with whom Lesley had many walks and talks on deck, "a man of quiet, gentle mien, but a clear eye and determined aspect, rather small and slight of build, poorly dressed, but a perfect gentleman. In the last days of the voyage he assumed a red shirt, a Kossuth hat, * * * his name was Rolfe. * * * He had been in all *nine* years in Africa. * * * Now he is on his way to join the new British Expedition to Abyssinia." Rolfe's high estimate of the negro races was a surprise to Lesley, but on arriving in Egypt the estimate was better understood. In Cairo he was grieved on seeing the oppression of the native Egyptians by the Turks. He discovered everywhere the original pattern of many of the

most characteristic parts of Gothic architecture, the transfer of which to Europe he ascribed to the "hundreds of thousands of priests, poets, artists, architects and noblemen" among the Crusaders, who imitated and improved on what they had seen in the Orient, when they returned to their western homes.

On the Nile the party met Mr. James Lawrence and his family, the Lawrence who that same year had generously provided means for Alexander Agassiz to visit Europe when he was making his famous "Revision of the Echini." Mrs. Lesley's journal of this excursion is illustrated with sketches by her friend, Miss Hale, in a style familiar to the memory of some now mature Americans from their early reading of the "Peterkin Papers," of which Miss Hale was author and artist, and in which Mrs. Lesley figures as the wise "Lady from Philadelphia." Some Europeans long resident in Egypt would not approve the behavior of the Hale-Lesley party, inasmuch as the lady members remained present at native receptions, in which the chief entertainment was provided by dancing girls, whose performance began "just as soon as Mr. Hogg, the missionary, had disappeared," and whose "motions it is impossible to describe." The Lesleys were interested to learn that it was "at Karnak, on the roof overlooking this strange country, that the elder John Lowell made the codicil to his will, in which he left the fund establishing the Lowell lectures." Lesley must have been in his element among ancient Egyptian monuments and hieroglyphics, but he seems to have been resting and left letter writing mostly to his wife.

The return from this most enjoyable journey was made rapidly through Italy and France to England, where April, 1868, was spent. At Oxford they saw Phillips; from Salisbury they visited Stonehenge, and there Mrs. Lesley, with more discrimination than her husband had shown in his letter from the Genoa-Leghorn sea trip, wrote:—"Nothing can exceed the politeness of all these literary and scientific English gentlemen. They are full of enthusiasm, as communicative as can be, and we have yet to see the first instance of what is called English coldness."

More Personal Items, 1868-1870.—The summer of 1868 was spent quietly in New England; the following winter in Phila-

delphia, where in 1869 the family moved to 1008 Clinton street, which was then their home for twenty-five years. Work was taken up slowly; at first as librarian and secretary of the American Philosophical Society, but during the summer in New England Lesley avowed "a strong desire to take up the topography of the Connecticut Valley, from Northampton northward, as a job of pure science for one, two or three summer seasons." A very little reading in geology was too much, so he kept to novels, newspapers and hieroglyphics. He wrote a dedication hymn for a new church in Keene, N. H., with Emersonian preference for pertinent meaning over purity of rhyme; surely "enough" and "love," or "porch" and "couch" go as well together as "squirrel" and "quarrel." He was asked to deliver an oration at the Humboldt Centennial at Philadelphia in September, 1869, but declined, and Louis Agassiz was chosen instead. The recreation of an afternoon game of billiards at the Union League Club began at this time, and was continued a regular habit for many years. Lesley declined a call to Cornell University as professor of geology, in 1868, because he dreaded entering into "new and perhaps awkward relations, with incessant daily work, great responsibility and competition with younger and better trained teachers. I should teach without having been trained to teach, make my illustrations when I ought to be asleep, read late at night, under anxieties about the next day's lecture, be called upon to visit and receive visits frequently, have my sympathies drained by young people, and get no holiday in the year, except during a month or two of the hottest weather." He enjoyed being master of his own time, "with no necessity for more than two or three geological excursions through the entire year," yet the following winter (January, 1869), apropos of some lectures in Baltimore which he described as "too pragmatic ever to be popular," he wrote:—"I was made for a teacher. * * * I should like to lecture an hour a day regularly, for a semester, to a class of honest, earnest, young students," and a few years later he gratified this wish, as well as the authorities of the University of Pennsylvania, by accepting a professorship there, whereupon he seems to have done with pleasure many of the things that he declined to venture upon at Cornell.

In 1869 he took the position of editor of a weekly folio, the U. S. Railroad and Mining Register, which he held for four years and in which he seems to have freely indulged his discursive inclinations: indeed his manner of conducting this task, which interested him intensely, must have sometimes astonished as well as instructed the business men whose interests the Register was supposed to serve, for his articles are described by a competent critic as "fresh, breezy, cheery, clear-cut, picturesquely flower-bestrewn, spicy, authoritative, editorial comments on railroad, mining, surveying, geological, scientific, philosophical, theological, political, politico-economical, American or European subjects of the day; in short, on things of every kind, and some others." Evidently it would be a curious world if we were all Lesleys, and a dull one if none of us ever had his extravagances and enthusiasms. It was apparently one of these articles, in which the Coast Survey was the theme, that called forth from Benjamin Pierce, then Superintendent, "a letter of overflowing thanks."

For a time after the long absence in Europe, Lesley did not undertake field-work; it was a year before he again entered upon the professional duties of a geological expert: even then it taxed his strength heavily. In July, 1869, he said:—"I wrote a whole report, and drew a map yesterday morning, and got a hundred dollars for it today. But it knocked me up a little." His correspondence grew to be large and varied; offers of large salaries were made for work that he was unable to accept, even though long experience had given him the power to see quickly and execute rapidly. In the summer of 1869 he was asked by "Tom Scott" of the Pennsylvania Railroad if he would entertain a proposition to go with a party to examine a million or two acres of coal, iron, gold and silver, in the Raton Pass country, Colorado, one week out, three weeks there, one week back; but he feared to undertake it. "It would be steady railroad to the west line of Kansas, two days' stage then southwest to Raton Pass. Camp life. Soldiers' escort. Horseback exercise all the time," and he wisely declined this too large opportunity.

In the early '70's Lesley made a number of visits to Virginia, Tennessee and North Carolina, and partly overcame his

earlier dislike of the Southern States. "I love the backwardness of the South. It rests one who is weary with the driving 'progress' of the North. * * * To plunge into the 'long-leaf pine belt,' as I shall tomorrow, is like taking a dip into the sea of the past." Yet he found the country desolate:—"Swamp, prairie, forest, log huts, negro shanties, here and there at long intervals an impoverished farmhouse * * * the landscape * * * flat, and vast, and worthless as its history. * * * The climate is superb. The people might be a mighty race." The hilly country of East Tennessee was more enjoyed. His host there met him with "two good saddle horses. * * * The Nolichuckee flows between fertile bottoms, at the foot of precipitous mountain walls. * * * The exceeding rare beauty of this scene cannot be described." His letters to his wife contain, at this time, occasional outbursts of satisfaction and pleasure over his own work;—"Congratulate me. I have accomplished one of the prettiest maps you ever saw, and did it all since breakfast today. It is now five P. M., and I am not at all tired. It is an Indian ink bird's-eye view of the valley of the Castleman's river, with all the coal and limestone beds running around the hill slopes. It is a beauty. I didn't know I was such a genuine artist. And I work more rapidly than I ever did in my life. Tomorrow I shall write my report, and get the whole affair off my hands and mind." It is gratifying to know that he recognized the excellence of his work and thus expressed his appreciation of it in private, though we may be sure he would have never done so in public.

A Characteristic Incident.—An incident of which Lesley told his wife and which she described to her younger daughter is so characteristic of the man that it deserves statement in full:—During one of his field surveys (1873) he spent the night in the hotel of an interior town:—"After tea, the bar-room looked comfortless, so he wandered up the street to see what he could see. At last he came to a lighted hall, and he walked in, and found about 30 young men seated on benches, but all very silent. He asked what the meeting was, and they told him it was the Young Men's Christian Association. He waited awhile, and no one spoke, so he rose and told them he was a stranger there, and not a *young* man, and perhaps he had no

right to speak in their meeting, but he should like to very much. Several said, 'Oh, yes, do.' So he preached to them for a whole hour, without a pause. He gave them the history of the associations that existed before the time of Christ, and those that had existed since; the objects and aims that had animated them, the causes of their rise, and their successes, the reasons why they had ever failed. And he ended with an affectionate exhortation to them to work for the salvation of other souls, rather than their own. Then he quietly left the hall. But they followed him in a body, thanked him in the most heartfelt way, begged to know his name and occupation, and what church he belonged to, and grieved that he would be going off in the early morning train. The minister insisted on his going home with him, and talked till midnight, parting from him in the most cordial and heartfelt way. He said the whole time was most interesting and carried him back to his old Colporteur days."

Many another geologist has found the bar-room of a village hotel comfortless, not to say repulsive; but how few have gone from it to preach for an hour, to the satisfaction of a village audience, on the history of religious associations through the last two thousand years.

A few years later a similar episode occurred, this time in the oil region, to be recorded by Lesley himself. When it was known that there was to be a lecture, "men and women flocked from all quarters and I was introduced * * * to three hundred of every age, sex, and condition, as 'Mr. Lesley, who would lecture on Geology.' Of course I couldn't. It was absurd. * * * But I talked for an hour; told them stories of the Challenger, and fish teeth in birds' bills; gave them a commentary of the Psalm, 'The heavens declare'; told them what rules my father taught me when a boy, to live by; described the Christian geologist as a 'barrel of oil'; passed an eulogium on science and solitude; and in a word held men, women and children in silent attention the whole hour, and received a vote of thanks at the close." This was before the days of moving pictures; it might be taken as a scientific precursor of the modern vaudeville.

Theoretical Views in Professional Reports.—Lesley's active

interest in theoretical geology as well as his discursive habit in writing naturally led him to include many discussions of a very hypothetical nature in his professional reports on coal and iron properties, a collection of which was bound together for private distribution in 1874. One of these reports is on the brown hematite iron-ore banks of Nittany Valley, near its crossing by the Juniata River at Tyrone, in central Pennsylvania, and is illustrated by a characteristic map in shaded 20-foot contours of Lesley's own drawing from Platt's field-work. It contains also two sections northward across the valley as far as Bald Eagle Mountain, which consists of vertical "No. IV" (Medina sandstone), along the southern base of which a great fault is shown, with the Lower Silurian limestone strata of the valley riding up over the younger vertical strata at an angle of 54° . A diagram section follows, in which a graphic construction, made on the basis of the observed dips of the less inclined strata north of the mountain, "results in giving a slope of 50° to 54° to the bassett edges of the broken mass" (north of the fault); and from this the conclusion is drawn that "it is evident that the upslide of the other [southern] section of the broken mass has conformed to this slope, and that the uniform dip of 54° observable for miles along the * * * foot of Bald Eagle Mountain * * * is perfectly explained by the diagram. This is the first time, I believe," Lesley remarks, "a solution of this difficult problem in structural geology has been reached; and its bearing upon similar phenomena attending up-throw-faults and broken anticlinals in other regions will be noticed by geologists. The theoretical deductions from this solution are important. It proves that the original fault was in a vertical plain, and not on a slant. It proves that the lower Silurian limestone mass has ridden upon this slope to a considerable height, probably several miles, in the air above the present surface. It illustrates the great erosion of the country, amounting to thousands of cubic miles of earth crust. * * *

This extract may be regarded not only as an example of Lesley's method of work, but as an example of a method of work that was characteristic of the earlier generation of self-taught American geologists and that is today very generally replaced by a more rigorously logical method. It warrants the

characterization that in temperament Lesley 'was strongly poetic and artistic, often thinking, reasoning and talking as a poet and seeing as an artist; embellishing with poetic imagery the vigorous originality of his writings and accenting with artistic touches the individuality which marks the maps and sketches with which he profusely illustrated his reports.' Lesley's graphic construction is full of patent assumptions for which it would be difficult to find justification; but they seemed reasonable to him, so he adopted them without further inquiry. The first one of his "theoretical deductions" is not obligatory unless various alternative constructions, which do not seem to have been considered, are left out of account; thus confident assertion replaces demonstration. The case is similar to one in which Lesley, when discussing with some friends the geology of a difficult region, full of complicated problems that he had hardly studied at all in the field, exclaimed with enthusiasm:—"Paleozoic strata once stretched all over New England. I'll believe that," he added, striking the table beside him with his fist, "till I die." The entrance of so much vehement opinion into geological exposition during those earlier years naturally led to many personalities in discussion; temporary tenacity of opinion sometimes made the meetings of "Section E" of the American Association more exciting than edifying. The modern meetings of the Geological Society of America are tame in comparison; indeed, many papers now presented there are so carefully and objectively prepared that discussion is discouraged; for when distinction is made between what geologists call certainties and what even geologists recognize as doubts, there is little ground for diversity of opinion.

The deficiency of the older method was not because logic was not then studied, but because it was studied in too formal and abstract a manner, and by students who were too young to carry it into application. Hence an investigator could then adopt as a verity any pleasing hypothetical explanation that he invented, without demanding that it should do more than explain the things that it was made to explain, and without searching for alternative explanations. Today formal logic is probably less studied than it was then, but geology as well as science in general is better taught; indeed, it is sometimes taught so well

in the more advanced courses that many principles of logic may, to the student's great advantage, be there learned inductively; and as a result vehemence of assertion and tenacity of partizanship are now very generally replaced in scientific meetings and writings by calm and well-balanced exposition, at the close of which the conclusion does not need to be held up, as if gripped in the clenched hand, but rests as if on the open palm, without need of protection, safe in its own stability. Thus geology has advanced in discipline as well as in content; but it must not be forgotten that the advance has been made by successive approaches closer and closer to the truth, and that among those who have contributed immensely to the advance was the vehement Pennsylvanian who so easily demonstrated that a fault-plane, which he "proved" by a series of convenient assumptions to stand now at an angle of 50° , was vertical when it was originally formed.

The University of Pennsylvania, 1872-1883.—Lesley's service as Professor in the University of Pennsylvania was an episode that gave him much pleasure. He had been nominally Professor of Mining there since 1859, but in 1872, when the University moved from its old buildings in the heart of Philadelphia into larger quarters beyond the Schuylkill, in the western part of the city, larger responsibility was placed upon him; he became Professor of Geology and Mining, and not long afterward (1875) was appointed Dean of the new Towne Scientific School, positions that he held eight years. He plunged at once into the work of teaching and of organization, and made hurried visits (1872) to New York and Boston to get ideas regarding equipment. He loved to impart knowledge and held the attention of his hearers by his whole-hearted enthusiasm and his unconscious absorption in his subject, rather than by authority or disciplinary devices. His generous disposition made him think well of his students, "all of them so bright and interested;" and they must have been amused at his peculiarities and extravagances; but they recognized his perfect candor and fairness, as well as his immense learning and his unselfish devotion to his work, and they respected him. He had his schemes at the beginning, of course:—for example, "I shall make my boys report my lectures and print them in facsimile to

spur them on;" but it does not appear that he exacted so heavy a labor. His real success must have come more from the revelations of his enthusiastic and affectionate personality than from systematic teaching.

On one occasion he wrote:—"I greatly enjoyed my lectures to the Sophomores today, on the contrast between God's immutability and the infinite variety of change in the geologic history of the earth; they sat like one great eye and ear, for an hour," and again:—"I had a lovely hour with a select ten of my Seniors this morning, over the history of the geology of New Hampshire; and I told them anecdotes of Charles T. Jackson, Josiah D. Whitney, the Braintree trilobite, etc., and gave them lots of moral advice against impatience, envy and all uncharitableness; and their fine unspoiled young faces beamed intelligent sympathy with all I said. * * * A few such opportunities sanctify a term, and pay for all the fatigues and anxieties of a course of lectures." And once more:—"I got another chance this morning to urge my Seniors to be thinkers, and not 'scientists' (and here this odious word comes pat),—gentlemen to boot—in fine, Christians. * * * It was on the occasion of my definition of the geological structure of Southern Virginia, after I had shown them in colors the difference between 'rich' and 'poor' valleys; in those, wealth and slavery, in these poverty, freedom, love of the Union." Human geology of that sort always holds students' attention better than the most learned lists of formations or of fossils; but human geology can be taught only after experience of humanity and by a man of sympathetic learning. Beginners in a science, few of whom are likely to follow it far, do not care for it in the concentrated form which pleases the devotee; and they care less for a systematic than for a discursive presentation, which Lesley could give to perfection. Lesley's wife wrote that her husband had "literally to drive the students away when hours are over, and now they are clamoring to work afternoons. He stood lecturing yesterday four consecutive hours, without a moment's let up, and strained his lungs so that he could not speak aloud all the evening. Peter says his boys are all angels, * * * but I know better. * * * He isn't reliable." Curiously enough, this experience in pre-

senting the principles of geology to young students did not confirm Lesley's belief in evolution. He had at first been inclined to accept Darwin's ideas, when they were fighting their way in the sixties; but twenty years later, when evolution was established, he turned against it, and would sometimes express complete disapproval of it:

Proof-reading, 1872.—During part of this professional period, Lesley still acted as librarian and secretary of the American Philosophical Society and as editor of the Railroad and Mining Register. As no sufficient aid was provided him by the Society, he had much drudgery in way of proof-reading for the Proceedings; indeed, the early habit of doing his own work later prevented his utilizing assistants as fully as he should have done. No wonder that he wrote in 1872:—"I am as busy as a bee, writing and reading for my *R. R. Register*, and my future lectures. I am very ignorant in Paleontology, and am coaching up out of Pictet. I am also publishing my survey of S. W. Virginia, with a map, and 20 wood-cuts. All the first edition of our No. 88 Proceedings of the American Philosophical Society was burnt up * * * and I have had to get out a second edition. Proof-reading of genera and species of fossils is *der Teufel*. But proof-reading Mr. Price's metaphysics is worse, for want of interest; and proof-reading of Chase's and Kirkwood's Astronomical Calculations is *der teuflest* of all. What a lot of rubbish I have shot into my soul first and last! But the Good Lord will not be hard on me, seeing I did not hanker after it, and would gladly have escaped it. * * * Yesterday I worked hard all day from 8 o'clock to 5. You know it is my only leisure day. Nobody interrupted me. I read proof of seven papers of Cope. He has discovered *wonderful* animals in the Rocky Mountain rocks, a hog got up with exceptional teeth to live on turtles."

It is doubtful whether Lesley was consciously sarcastic in speaking of that yesterday with its long hours of work on proof-reading as his "only leisure day." With all these wearing duties it was to his Egyptian books that he turned for relaxation. He could forget all care in the society of his beloved cartouches and the long procession of the dynastic kings. Thus he tells that in the dog-days of the summer of 1872:—

"In sheer desperation last week at the intolerable heat, and over-press of this sort of trash work [proof-reading as above], I laid everything aside, and got down into the parlor my Egyptian books. Three days I worked away, and late at night. * * * It didn't hurt me a bit. * * * I have got down now in my MSS. to section 431: or to Reneferareka, 4th King of the Vth Dynasty. I have several kings of the Vth, and the whole of the VIth to do. It will take me another year or two, for oftentimes months pass without my being able to look at it." Yet all this was for himself: "I do *not* bore the world with my private amusements and recreations."

The "Second Survey," 1874-1894.—Lesley's service for twenty years, 1874-1894, as head of the Second Geological Survey of Pennsylvania, was the culmination of his life work. He was indisputably the man for the place; his previous work for the First Survey in field and office, his abundant experience as geological expert, and his extraordinary familiarity from direct personal observation with all parts of the State placed him above competition. When appointed, he entered upon his duties with enthusiasm, although his salary as State Geologist was small compared to what the private practice of his profession would bring, and the responsibility was heavy and unceasing. But he knew his opportunity and seized it eagerly, for he had these many years been anxious that a thorough survey should be made of his well-beloved Pennsylvania, so richly endowed with useful minerals and so abounding in geological problems of high theoretical interest and enormous practical importance. He had, previous to its establishment, advocated the organization of the Survey in and address in which he outlined its object as economic rather than scientific, and proposed the policy, later adopted, of giving full independence and prompt recognition to the work of assistants by the immediate printing of their results in reports of progress. He had already insisted on this point in "Coal and its Topography," in which he said:—"No primary report should receive the touch of any hand but that of the first observer" (p. 212). This was an evident reaction from the opposite policy of the First Survey under Rogers, which he had so violently condemned, and like most reactions, it was carried to an extreme.

It was based upon the excellent theoretical principle of individual responsibility, but it did not sufficiently recognize the importance of discussion and concentration before official publication; hence it led to the printing of voluminous original notes, minutely detailed and frequently undigested, made for the most part by assistants who had had little previous training in geological field-work and less in writing geological reports, and who were nevertheless left practically to their own devices in the field.

As a matter of fact, the original records fortunately received a great deal of conscientious editorial work from the Director in order to make the published reports of progress intelligible and methodical; indeed, the records were, in the opinion of some of the assistants, practically written over again. These young men frequently discovered parenthetical comments or argumentative footnotes that had been added in proof by the Director and that they felt were not in every case edifying; but Lesley knew the State so well that when the 'assistants arrived at conclusions contrary to his own, he felt compelled to present what he believed to be the more accurate conceptions.' Indeed the Director 'could never forget during the early years of the Survey that his assistants were inexperienced, and his constant anxiety was to prevent that lack of experience from doing injury either to them or to the State.' There is little question that the changes and corrections he introduced were for the most part well grounded, but it would have been better if all such differences of opinion had been argued out to agreement, as some of them were, instead of disclosing them to the world by publication. The Director was indeed severely criticized by some of his assistants for revising their reports; but the real fault lay not in thus violating the principle of independent responsibility, but in the principle that was thus violated, even by the Director who had proposed it. A geologist may, of course, independently publish his peculiar individual ideas, which run counter to the views of his colleagues, in the proceedings of learned societies, but it is quite another matter to publish them in the reports of an official survey.

It was not only that the Director frequently found it necessary to rewrite large portions of these manuscripts; he actually

drew or redrew a large proportion of innumerable maps, sections and illustrations; thus he himself, apparently unconscious of the way in which his remarks showed that he not only supplemented but supplanted the reports of his untrained assistants, told of imaginary whispering from some one behind him about the work he had to do:—"Have you finished Carll's drainage map? Bien [the lithographer] is waiting for Frazer's Susquehanna section, which nobody but you can do!" Any one familiar with his excellent literary style and his admirable graphic skill must feel confident that improvement was made in such cases, and must therefore rejoice that the crudities of his young assistants and the unwise principle of their independent responsibility in official surveys were both sacrificed for the good of geology and the advantage of the people of Pennsylvania.

The Drudgery of Survey Work.—The Survey work cost Lesley dear in time, fortune, position and strength; it absorbed all his working hours, it prevented his accepting much more lucrative work, it compelled his abandonment of university duties, and it broke down his health; but it was his pride and his glory, and the sacrifices that it demanded were willingly made. "I never wish for wealth when I am in my own house, but I never fail to long to be wealthy when I am in a place free to the public. It is so noble a vocation to serve the commonwealth; to distribute delight and instruction to the multitude. * * * All I ask now is to spend or be spent for the good of my kind." Yet the sacrifices were in one sense unnecessary, for they resulted in large measure from his unfortunate habit, probably acquired when he was striving single-handed in earlier years, of charging himself with details that ought to have been done by his subordinates. That he should have had to justify the continuation of the Survey and secure biennial appropriations for its support, and that he should have read all his assistants' reports and prepared summaries of them in the form of prefaces, was admirable; but that he should have exhausted himself with writing innumerable letters, preparing indexes, "waxing models," reading proof and drawing diagrams, keeping track of drafts, vouchers and checks, is regrettable, even though he performed all these petty duties excellently well.

'Every page of the one hundred and twenty bulky volumes published in these twenty years passed not once merely, but many times under his careful eye * * * he took personal charge of every step in the publication,—from the choice of author to the finished volume on the shelf.' The work wore him out and prevented the full accomplishment of larger tasks which he alone was competent to perform. This he saw clearly:—"I long to be called upon to express some grand old thoughts once more. But for this, one must be emancipated from petty routine labors. * * * I am trying therefore to make the Survey automatic, so that I may be freer for the more difficult and delicate functions. * * * If I do all the drudgery, I become incapable of investigating, reflecting and expressing in a large way, the results of the Survey." But he seems to have been unable to reform his habits, and was always overwhelmed with work.

Lesley was sometimes amused at his own distracted condition. He wrote after a spell of hot weather in the summer of 1875, when his work held him in Philadelphia:—"My wife is gone, my children have gone, my knife is gone, my pen is gone, my spirits have gone, and everything but myself is gone, but I cannot go. * * * Oh, how hot it has been. * * * Some day there will be an advertisement in the *Ledger*: 'If any one can give any information as to the whereabouts of a State Geologist, his afflicted corps, printers, artists, and well-wishers will be duly thankful.'" A few years later:—"You don't know how hard it is for me to write a letter, when at every paragraph a voice behind me whispers: 'How about that roll of proofs?' * * * 'What do you think about the risk of letting those two hundred pages of [an assistant's report] go to press without rewriting them?' 'Have you examined that pile of * * * MSS. sent in by F. P. day before yesterday? You know the sections must all be arranged by you * * * or he will get them wrong,'" thus again revealing a practical interpretation of his theoretical views regarding the independent publication of assistants' reports! Sometimes he was pitifully discouraged, and even at the end of the first year of the Survey thought the burden too heavy to carry any further. A hard day's work made him exclaim:—"I get so tired of the dry facts

and tedious statements of my science, this restless wheel of publication round the year, which never stops."

But between amusement and discouragement caused by his overworked condition, there were many expressions of high satisfaction. Thus after several years of Survey duty, he wrote:—"My organization of the Survey is bearing an incredible harvest, so copious and excellent that I am amazed at it. The animus of the corps is of the finest order, and is as good-humored as it is zealous. * * * I thought I should never have opportunity, nor means, nor time, nor strength, to publish my researches; but, on the contrary, fifty people have suddenly rushed up to me and surrounded me, offering with zeal and intelligence all and more than all the aid that I require. In fact, I am embarrassed with the abundance of opportunities, and the wealth of means. * * * It is no light thing to be the virtual owner of \$50,000 a year, to expend as you please, without let or hindrance, for the realization of a noble idea. Such is my good luck. * * * If the Legislature pleases to continue the Survey, our volumes of reports will number fifty. * * * They are not fancy work; they are full of solid and well-digested facts. You can imagine my hen-like clucking over each of them."

Satisfaction is sometimes lost in the overpress of drudgery; thus in April, 1884:—"The moment I got through with [a certain report] I rattled off three long-delayed pieces of work and expressed them to their respective places. Today I have made good headway with the Berks Co. map, which has been staring me in the face since February 1st. In a day or two that will be sent off. Then I tackle the deserted remnants of Delaware County; and then—well, I shall begin to print d'In-villiers' 400 pages, Claypole's 800, and White's 600—1800 pages MSS. to read proof of, preface and index, besides all the illustrations to lick into shape, before August." Two years later:—"I am excessively tired—have been so for several days—right elbow painful, arm like lead, too constant writing, too much *Stromatopora* bed in No. VI— * * * too many references to verify—too many drawings to hunt up—too much grinding of slices for the microscope—too much geology with too little comedy—in fact, too big a book on hand for one old brain and

one lame hand." The report on the Terminal Moraine (Volume Z) for some reason proved a "perfect nightmare, lasting six months."

If one must regret the time given to draftsman's work by the Director of a Survey, one cannot grudge him the joy he found in it:—"I bent over my map all this morning, thinking * * * of those ages on ages during which the mountains which I was coloring in were being deposited and the valleys being eroded. * * * As I laid in the colors, and brought them by a thousand patient touches to harmony, so by a thousand patient touches of the Divine hand we are gradually fashioned into what we shall be." Six years later:—"I have been drawing a topographical poem all the last week, and never enjoyed anything better. I alternate drawing and writing, to rest and refresh myself."

Distractions and Entertainments.—Lesley was at this time a tall and striking figure. In manner he was more awkward than graceful: his clothes hung upon him without close adjustment; his face was strong but not handsome; his smile was kindly and charming; his voice was pleasant and melodious. Thick glasses and long hair gave him an appropriate singularity of appearance. Even before the Survey work was begun, Lesley's family and friends were apprehensive for his health, and after it was undertaken they marveled that he could get through so much work without any worse consequences than temporary fatigue. In the first years of his directorship insecure health required him to live by rule; he usually gave six hours daily to concentrated labor and then closed his office; but later, when the completion of certain tasks within limited periods required haste, his day knew no measure, with the inevitable result of all work stopping before it was finished. Regular and temperate habits of living helped him for many years; he kept up his daily games of billiards at the Union League Club, and was a faithful attendant at the Sunday evening gatherings of Philadelphia intellect at Fairman Rogers' house. He believed that change of occupation gave rest, and thus excused some of the semi-mechanical "drudge-work" to which he turned when too fatigued to write; his Egyptian studies served a similar purpose; he tells:—"When I get tired of task work, I read my

‘Neue Kambyses.’ It is full of the most interesting things. * * * I have found accidentally this evening [1876] the explanation of our printers’ *Vinculum* { . It is immensely old ; in fact nothing but the — or extended arms which the Egyptian priests used to signify the *summation* of a set of kings’ reigns.” He seems to have been conscious that such an explanation made a leap over long periods of time, through which it ought to be traced—although he does not seem to have had a similar perception of the uncertainty of some of his etymologies, as in the case of Tory, cited above—for he later laments:—“I despair of ever finding that time and patience, that solitude and leisure, that physical and intellectual endurance, which I need to classify, criticise and explain my mass of notes. They will remain after me as a curious monument of wasted years.”

Grief over the death of old friends and the ever-lessening number of the survivors is often expressed in these years of fatiguing work:—“I am already, at sixty-one, lonely in the world. Of my familiars, Hodge, Henderson, Whelpley, Jackson, Haldeman, Frazer, McKinley, Towne, are gone; of my elder intimates, Agassiz, Bache, Henry, Rogers, Trumbull, I never see; * * * my Boston friends are far off. * * * Desor alone remains in Europe. * * * How narrow a circle of real near dear friends any one can have! * * * Some of the young men love me; but what can they know of me?”

But fond as he was of his friends, formal observances, as of birthdays, did not interest him:—“I don’t care for anniversaries myself; they mean nothing to me. * * * I suppose the sentiment was early eradicated from me, by my archæological studies, the investigation of secular eras, the comparison of immense confluent geological ages, and all that. The consequence has been *that all time* is to me confluent,—one grand unit. Past, present and future seem to me the same. What has been, is still, and will be again, a thousand times repeated:” but even in reading this outburst one half expects to see a contrary opinion stated with equal emphasis in another letter, written a little earlier or later in a different mood.

Lesley’s reading still covered a wide range; in a single letter he refers to Gladstone’s articles on the Olympian gods, Sir

Grant Duff's review of English change in opinion, and Mivart's defense of the Catholic attitude toward science. There was also much reading aloud in the family. The father was fond of fairy stories and had a bookcase full of them; he loved romance and "its wizard, Walter Scott. * * * How loudly the old heart can still beat at the story of the loves of two young people; * * * but alas! who can write a novel, now that Walter Scott is dead. * * * 'The Newcomes' have been a dead failure. * * * This is the second time I have tried to like, to endure Thackeray. * * * He is simply detestable. His Colonel won't save him. * * * So we have abandoned Thackeray, once and again, and forever." Lesley took time to write two religious articles; one was entitled "Shall we call Him Master?" and appeared in the "Forum" for January, 1888; he says that it contains "a fresh stream of thought; very suggestive for different kinds of readers, and perfectly unconventional;" of the other he tells that he advised the editor not to accept it, as it was not worth printing—but he was glad to receive \$100 for it.

Even if intensely fatigued by his University and Survey duties, Lesley's life was greatly enriched by them and by the new relations into which they led him; and with this enlargement of activities came a change of heart regarding his native city, against which his residence of several years in and near Boston seems for a time to have turned him. During the early part of their residence in Philadelphia, both Lesley and his wife had a feeling of loneliness, and a craving for a return to New England. During a visit to New England in 1876, he exclaimed:—"This Boston world is so full! At last, however, I regard Philadelphia from a distance, and with something approaching a genuine affection;" thus recalling the regret with which both he and his wife had left Milton in the early '50's, and suggesting a long-delayed domestication in the Quaker City. In reply to a letter from a daughter in Boston, in 1878, he wrote:—"Nearly forty years ago I was writing from Boston home [to Philadelphia], such letters to a father who loved me entirely as I love you. With this difference, that he knew nothing of Boston but as a place of dangerous *isms*, and nothing of the people who lived there, but as Emersonians.

Parkerites, Garrisonites, *et id omne genus*; whereas I have lived and loved there, and believe both the place and people to be as nearly perfect as the age and the earth permit." A few years later he remarked:—"I can easily see that at last our many years of endurance in this *city of our exile* have ended in making it a true home;" and later still:—"I have always disliked my native city. But I have at length come to regard it as my true home, and become reconciled to the once hated idea that I shall always live in it, and die in it, and be buried in it." This feeling deepened in later years [1891], when he wrote:—"The country was in its prime of summer, but somehow not so beautiful to me as the little back alleys of Philadelphia, through which I am accustomed to saunter and dream on my way from 1008 Clinton street [his home] to the Union League house in Broad street. I love the little streets and little houses and little people living in them. * * * I was born in a little house."

Lesley at this time as always depended greatly on his wife, whom he recognized as "so sweet and uncomplaining," in his "injudicious and variable moods"; while she, without neglecting the cares of the household, found pleasure for many months in the task of reading, arranging and selecting her mother's letters, a labor of love into which she put her whole soul, and thus produced her volume, "Recollections of my Mother," at first privately printed (1876), but later issued in three larger editions (1886, 1889, 1899), which many critical readers have enjoyed, and of which Emerson said to her:—"I cannot tell you how many times I have read it over. * * * It is a unique picture of New England life, and of an individual character." Somewhat later, Mrs. Lesley took an active part in the Organized Charities and Children's Aid Society of Philadelphia, in which she was for a number of years a valued and influential worker. And yet her husband once wrote to his brother:—"Nobody to talk to. Not a soul in the world but you. Wives and children are nice, but they are not *men*. They are too dependent. They look *up*, not *down* on you. They are parasitic, not fundamental."

With all his occupations, Lesley maintained his exuberant interest in many matters apart from geology. He enjoyed

music and plays, novels and fairy stories. He underlines in a family letter the fact that:—"Dr. Draper has in fact discovered oxygen in the sun! and allows the A. P. S. to have the honor of first publication. 'Saturday morning all the telegraph wires of the world will announce Oxygen in the Sun.'" A little later he writes:—"The discovery of Mars' moons, so small and close and quick, distresses me, like a contraction of the forehead or chest." Attracted for a time by the theory of evolution, he now turned against it, repelled at least in part by Haeckel's extreme views; he called it "the prevalent epidemic scientific superstition of the day." He was not always serious; his letters contain not infrequent humorous, or would be humorous, lines:—"We elected Prime Minister Gladstone a member [of the American Philosophical Society]. Will he not be proud! My dear Society has its ludicrous aspects, like most old people, places and things." An address that he was to make at Smith College seemed in prospect "like a missionary's sermon on landing in a foreign country. I do not know Smith College or the Smith Family, and as they are all girls I shall make some great blunder." He turned many excellent phrases:—"Laws and generalizations get mighty tedious without facts. Facts are the little children in the Tuilleries garden; laws are their *bonnes*. What would a garden be full of *bonnes*, without the rollicking crowd of little babies about them?" * * * "Passing events of the most impressive character slip into oblivion—accidental details of no moment catch in cracks of the brain, and stick there to all time, like the boulder in the Flume of the White Mountains."

The American Association.—Lesley had sensible ideas about scientific gatherings: when he was president-elect of the American Association at Philadelphia in the summer of 1884 he held the meeting down to business:—"A most successful meeting it has been, a brilliant meeting, a harmonicum and melodium of a meeting, and everybody says so. The arrangements were laboriously and skilfully made. * * * There has been no fuss and no feathers, nothing tawdry, no noise, confusion, or crossing purposes,—little or no guzzling, no toadyism, and scarcely an ounce of padding in the list of papers."

It must have been the fatigue coming from the drudgery of

his work in editing the many reports of the Second Survey, a duty that he too faithfully performed, that led him to select for the chief topic of his address as retiring president of the American Association in 1885 the importance of what he called "Dead-work"; that is, the collection, comparison, and correction of data before the announcement of a result. Perhaps he felt that even his own impetuosity needed to be curbed, for though he loved the remembrance of his youth, he regretted its "dogmatic impertinences," and he deprecated the presumption of young recruits who rush into the thick of a discussion with their premature solutions of all its difficulties. One must, however, think it unfortunate that he could not have prepared an address upon a more live subject, especially as it appears that he had thought of discussing "the influence which anticlinals and synclinals *en echelon* have exerted in originally directing, and afterwards perpetually shifting, the systems of river-drainage, as the general surface became lower and lower through erosion"; thus recognizing in that problem a proper subject for serious study, and warranting the interpretation of "overwork" placed a few years later upon his fatigued reply to a request from a younger correspondent for information on certain points about Pennsylvania valleys:—"I am worked to death just now by the printers at Harrisburg, and cannot look up references, even if I could remember writing about valleys which I do not, except in the two publications you quote. Nothing *new* can be said of it which would be true, and nothing *true* which would be new. It is an exhausted subject, and very little to be said about it anyhow, for a valley is simply a hole dug in the ground." Lesley's real nature had abundant kindness and encouragement to younger men, as all knew who knew him: this discouraging ebullition on a postal card was fully explained by its first sentence.

Trips to Europe.—Rest and recreation during these ten years of hard work were found in repeated visits to Europe with one or another member of his family; the dates of these journeys are:—July, 1874; July, 1876; July, 1878; April, 1880; December, 1881; June, 1884; April, 1887; April, 1888. During the visit of 1876, he greatly enjoyed a stop of several days at Desor's home in the Jura, where he read the names on the

trees. "Alas, more have the fatal cross, even those which are newer than our visit in 1867: Lyell's for example." The old comrades felt their intimacy of twenty years before renew itself as they talked together; they discussed "Süss's new radical hypothesis of Moon bubbles on Earth. * * * He [Desor] agrees with me that such speculations are *not* geology. * * * The more I see of the geology of the day, the less I respect the so-called leaders and masters of the science."

During a walk to a Jura gorge, they had "a furious discussion over its construction: I maintaining that it was produced by erosion by the little river which rushed through it, he that it was a transverse break not at all eroded. * * * Desor is wholly wrong in his interpretation of these fine phenomena * * * the erosion * * * has been enormous, he considers it insignificant. * * * I burn now to spend a summer in the Jura. * * * The Swiss geologists * * * are twenty years behind us." These remarks are of interest as showing how rational Lesley had become since the earlier time of his cataclysmic theories.

Lesley's comments on the International Geological Congress at Paris in 1878 are amusing:—"Everybody talked all at once. Three sometimes spoke vehemently without listening to each other. Total absence of parliamentary rules. * * * [James] Hall opened the [afternoon] seance with an English speech. Nobody could understand it. I resolved then to speak in French myself. * * * There are no German geologists here and no English geologists. This fact is ruinous to the success of the Congress. * * * Still it is a fine thing to come face to face with all these men. There are three hundred, more or less, present. * * * I read my paper on the Permian of S. W. Pennsylvania, and was complimented by a great silence of the audience, by hand-shaking on the platform, by a little speech of the president Hébert, who said I had done another great service to the congress, in showing that while lithology remains the same, the palæontology may change completely."

During the voyage of 1880, Lesley was asked to lecture on shipboard:—"I gave them an account of the rise and fall of continental areas, the ages of the great mountain ranges, and the dynamics of faults. An hour and a half was very agree-

ably spent in questions and answers, and I heard the Captain's chuckle from the far end of the saloon." Reports to write and maps to draw were carried over on this journey, and the inveterate worker enjoyed his freedom from interruption during a month in Paris. He then made another visit to his old friend in the Jura, whom he loved so much. "There are moments when Desor's furrowed face is both beautiful and grand. He is now one of the most strikingly picturesque of men. He has great dignity of carriage and language, and is very charming in his deportment towards all; everybody in the street takes off the hat to him. * * * He made me give him a full account of Hayden, and King, and Pumpelly, and Newberry, and his old crony Whittlesey, and Powell, and Wheeler, and Shaler, etc., etc." The winter of 1881-82 was spent mostly in Paris, where the geologist transformed himself into the writer of a story about himself under the name of "Paul Dreyfuss," afterwards published; he seems to have enjoyed turning to this play from the "shamefully neglected geological description of Perry County. Damn Perry County!" He found the chimney pots of Paris delightfully inexhaustible objects of contemplation, and quite as interesting to draw as fossils. "They might be classified in at least twenty genera, and two hundred species." The last journey abroad was made with his wife in the spring of 1888; and extended as far as Florence, where his younger daughter and her husband were then living. On the return he stopped at Zürich and saw Heim and his "ravishingly beautiful" models, "before which ours are as archaic as Lombard statues to those of Donatello." What other American geologist would have made such a comparison!

It was while he was abroad in 1882 that Lesley wrote at Nice, in response to a request, an account of himself, from which the following extracts are made: "My chief service to American geologists has been my early adoption and gradual introduction of contour curves in geological field work; in my persistent advocacy of equal vertical and horizontal scales for geological sections, and my use of contour curves for mapping beds and veins beneath the surface. The only original ideas in geology for which I could venture to claim credit are, 1, the determinations of the present system of surface drainage by the

dimpled form of the plicated original surface, and 2, the production of all modern topography chiefly by the underground dissolution of limestone strata, of all ages. These fundamental ideas as I have long considered them to be, have not yet been discussed, and therefore not yet accepted, by geologists, and I must trust to the future for their justification." But he begins all this with a disclaimer:—"I have done nothing worthy of record in Science." The verdict of posterity will be otherwise; his life was one of great accomplishment. At another time he wrote: "I was never anything but an amateur except in topographical geology. In that indeed I have been a master, inventor and founder of a school, which has now many professors who have all been in one way or another my students."

Volume X.—The progress of the various Survey reports is reflected in family letters. Lesley tells his elder daughter about the invaluable "Volume X," containing geological maps of all the sixty-odd counties in Pennsylvania on a uniform scale of two miles to an inch and with uniform geological coloring, all preceded by a concise text for each map. He gives an amusing account of his work upon it:—"I had to turn to and color the little State map, which is a skeleton key to unlock all the various locks of the sixty-seven cells in that penitentiary of knowledge. * * * Then I had to write a geological preface to the little atlas, a concise description of the structure of the State—a sort of detailed forlorn hope, carefully picked from our entire army, for dangerous special service,—against the legislature. When that was sent to the printer at Harrisburg, an experiment had to be tried. I began with A Adams, A Alleghany, A Armstrong, B Beaver, etc., etc., and wrote a two or three or four page description of each in turn—as it were, sending out a stronger force to support the forlorn hope in the attack. Only seven battalions as yet have marched,—sixty more are waiting orders. * * * I am pleased to see that others are pleased with my method and manner. * * * At the rate of three per day and two pages apiece, the sixty counties to be described will cost *me* thirty days of hard, very hard, thinking and writing, and the *compositors* about twenty more pages of small type to add to my preface. But the little book will be a beauty and make a sensation," and in this estimate the author was cor-

rect, for few if any of the one hundred and twenty Survey reports has had greater use than this one. True, it ought now to be superseded by a new atlas in which topographical form as well as geological formations shall be shown; but as long as no such new atlas is issued, "Volume X" will be in demand. No American geologist ought to pass his thirtieth year without having made a journey across Pennsylvania with this report as his companion. It would then be understood why Lesley enjoyed preparing the prefatory text, and why he thought the maps "very pretty," as they certainly are; but some of them cannot be very accurate, for he wrote:—"Somerset [county] I have yet to do and it will be a difficult task; as I must * * * interpret as I best can from my old knowledge of the region, where Hodge and I camped in 1839,—forty-four years ago—think of that! Think of printing in from memory old camping-grounds after forty-four years!" But that seems to be the way in which maps have to be drawn, in the absence of surveys on which to base them! The pity is that no proper topographical base was prepared by the Second Survey for its geological maps. In any case the Director made the most of his resources, and if any one ever deserved commendation for work accomplished, he surely did; but he does not seem to have cared much for material rewards; he wrote in 1889:—"Everybody is congratulating me on the gold medal awarded me at Paris for 'original investigation,' as if I had made the survey, and as if I had invented a new 'monkey soap,' and wanted a medal for an advertisement."

The Dictionary of Fossils.—The preparation of the three-volume "Dictionary of Fossils"—Report P 4, issued in 1889-'90—was an arduous task, and like many such tasks demanded more time and patience than was expected when it was undertaken. It seems to have been begun in Florence during a trip abroad in the spring of 1888, when Lesley spent six or more hours a day on it; he later wrote:—"I am learning a lot of Palæontology which I should have had the mastery of by rights years and years ago. * * * I am buried in a beautiful hades of fossil forms, and wander among them like a poet in a flower garden. * * * How beautiful and curious they are!" Lesley seems to have had a great respect for paleontology, al-

though he was not a specialist in that subject; for he said:—"If Homer's Iliad is immortalized, James Hall's Palæontology of New York, a more sublime epic, will have a more genuine if not a longer immortality." And again:—"Among the ugly crowd [of the Second Survey Reports] one beauty walks. It is our dear old Lesquereux's masterpiece, the Fossil Flora of America, illuminated by seventy or eighty plates of all sorts of ferns, and leaves, and tree bark of the Coal Era." The Dictionary was prepared and written out almost wholly by Lesley himself; it required the making of a card catalog of Pennsylvania fossils from whatever source—except the fossil flora, which had been reported upon by Lesquereux and Fontaine—and arranging the cards in the alphabetical order of generic names, with a figure for nearly every species. He was greatly aided by a number of correspondents to whom he sent the Dictionary in successive batches of galley proof, which they returned with comment and corrections. Lesley was well satisfied with his work, and regarded it as a completely successful experiment. "The book * * * has evidently made a sensation, will bear good fruit, and is jolly nice work." It was in great demand, and must certainly have served to popularize a difficult subject, although the expert paleontologist would probably find imperfections in it.

Summary of Pennsylvania Geology.—Although the Commissioners, under which the conduct of the Survey was placed, were friendly to its director, their advice does not seem to have controlled the action of the State Legislature sufficiently to have assured the continuance of appropriations; hence there was a period of anxiety at a certain stage of each biennial session, when it was decided whether work should go on or stop. The uncertainty made it difficult to retain assistants on the Survey corps, who became valuable elsewhere as soon as they had been trained in their work; and besides the young men would get married and leave this precarious employment for permanent positions elsewhere. The difficulty increased in 1885, when the Governor of the State, who privately assured Lesley that he was a friend of the Survey, attacked it on account of the vast number of its publications. As the number of volumes increased, each dealing with some restricted area,

the need of a condensed statement of the results gained became pressingly apparent; and in response to this demand Lesley, a tired man, undertook in 1885 an overheavy task in the preparation of "A Summary Description of the Geology of Pennsylvania." He completed two of the three thick volumes, but broke down completely before finishing the third; his lamentations when the impossibility of finishing the work was recognized are pitiful. He proposed in a mood of preliminary enthusiasm to write the Summary in Saxon English, "for the use of the people of Pennsylvania, in whose vocabulary Norman English has never been domesticated, who greatly prefer before and after, or before and behind, to anterior and posterior, and overlaid and underlaid to superimposed and subjacent;" moreover, the Summary should be "almost wholly a practical description of facts * * * not at all influenced by geological theories;" but it is hardly necessary to say that neither of these good intentions was carried out. On the page immediately following the explicit statement about Saxon English the author wrote that he had been "precluded from inserting" something; and all through the volumes one constantly meets such non-Saxon words as sequence, submergence, sedimentary, speculation, metamorphism, phenomena, ornithologist, pachyderm and a host of other classic foreigners. And as to the attempted limitation of a Summary of Pennsylvania geology to a "practical description of facts," any one who has analyzed the content of this flighty science will know that such limitation is utterly impossible. Most of the so-called "facts" of geology began as questionable speculations and are now nothing more than well-supported and generally accepted inferences; for example, the progressive deposition of the layers of bedded rocks, the organic origin of fossils, the former continuity of faulted strata, and so on with nine-tenths or ninety-nine hundredths of the statements that are commonly encountered in geological treatises. Even the simple statement that the hills of western Pennsylvania consist of horizontal strata is an inference, for the facts that are really certified to by observation touch only the discontinuous outcrops of some of the more resistant strata on the hill slopes; the very existence of the intervening strata and their extension through the invisible

body of the hill are pure inferences. There is, of course, not the least objection to the acceptance of such inferences, nor to the brief form of statement in which they are commonly presented as if they were "facts;" but they are inferences all the same. But it is not only well certified inferences of this kind that abound in Lesley's Summary: there is not infrequent mention of evidently hypothetical matters, regarding which various shades of opinion may be entertained; for example, the "shape and size of the Appalachian sea at the close of the limestone age" is still a fine subject for speculation; and when it comes to the early condition of the earth, which "got itself encrusted with a rind of solid rock, which no longer shone with dull red light of its own," many a reader will agree with at least half of Lesley's rather flippant statement that this "is only known to God and Dr. Sterry Hunt."

Let it not, however, be imagined that the above captious comments are directed against the Summary which is presented in these indispensable volumes, for it is a most serviceable epitome of the results that are otherwise to be found only by searching through the one hundred and twenty or more separate volumes of Survey reports; the point of the comments is to make it clear that the execution of the Summary is much better than its plan; for it was visionary to imagine that a summary of this kind could possibly be written in Saxon English, or that it could be almost wholly limited to facts; geology is largely a speculative science and its language is largely non-Saxon, as the contents and the style of Summary abundantly prove. It is to be feared that even a third element in the plan of the Summary—namely, that it should be written "for the use of the people of Pennsylvania"—could not be realized; for although the Second Survey cost about \$1,000,000, to which sum each voter contributed about three cents a year for some twenty years, it is to be doubted whether any large number of the comparatively few voters who received a copy of the three volumes of the Summary ever read them through. Geology is not only a speculative science, it is also a technical science, and apart from the merest outline of its results, which might go into a thin pamphlet, it cannot be presented to the people of a State in a form for their apprehension. The Summary De-

scription of the Geology of Pennsylvania is a monument to Lesley's profound knowledge of that grand subject; it is indispensable to geologists who are concerned with the study of the Keystone State; but it is not a popular book, and to one acquainted with the labor that it cost its pages are sad reading. It was begun with some pleasure:—"I am writing my summary slowly, but enjoyably, and with a quiet firm sort of confidence that it will be worthy of its subject"; but a year later fatigue and discouragement made him take a gloomy view:—he was "tired to death" of the work; "it is so frightfully monstrous, so unsatisfactory * * * of so little real use to anybody." Later on he says:—"I have safely explored and passed up through the Azoic Hell, the Cambrian Purgatory, and six lower heavens. I am now [1892] flying merrily through the Seventh Heaven, called the Oriskany; a crystal heaven, for it furnishes all the glass sand wanted at Pittsburg and elsewhere."

The book was harder to write because it was a work of compulsion:—"No gentleman can fail of his promise. I have pledged my honor to do a work in which my heart has no concern. I must finish my book. But how different is my interest in it from that which I once felt in every piece of scientific work which came under my hand." Disappointment overtakes him:—"I work and work and accomplish little. I work every day from nine to four, seven days in every week of the year. I have no holiday. I am buried in my big book. * * * I had to look over back pages of my Summary yesterday. Alas the style. Alas the *lacuna*. Alas the prolixity, the needful revisions, the awful proof-readings, the multitudinous illustrations to be made." He worked when he should have rested. "It will be the chief failure of my life." "If all geologists would promise me personally not to read my Final Report, I should be in no distress of mind whatever; for I can teach the Laity." Yet it is precisely to geologists that his Summary has proved most useful. One of the Survey assistants writes regarding it:—"It sets a standard for governmental reports. Nowhere can be found a more lucid exposition of facts and principles, unmarred by the assertion of personal theories, unbiased, thorough and complete." Another assistant writes of it:—"He gives full credit to each member of his staff, while

important phenomena, observed by the assistants, received full discussion from the standpoints of his broad reading and his own field work. There is no attempt to evade anything, no inclination to undervalue the work of those disagreeing with him; on the contrary, there is a frank presentation of opposing views, and frequently a retraction of opinions long held very dear by him." These commendations were written after Lesley's death: but here is one which Lesley had the pleasure of reading in a letter from a master of good English, Sir Archibald Geikie:—"The introductory part of Volume I. [of the Summary] is capital reading and will, I am sure, carry many a reader onward, to explore the rest and more technical parts of the book. The vigorous writing especially delights me, for geologists, as a rule, never cultivate literature, but express themselves in the most slovenly way."

Recognition.—It has been said above that Lesley was one of the fifty original members of the National Academy of Sciences at the time of its organization in 1863, and that he received a gold medal from Paris for original investigation in 1889; further, that consistently with his habit of minimizing his own merits he made light of both these high honors. He was also a fellow of the American Association for the Advancement of Science and its president in 1884-'85; member, librarian, secretary and vice-president of the American Philosophical Society of Philadelphia; member of the Academy of Natural Sciences of the same city, of the Boston Society of Natural History, and of the American Oriental Society; original member of the Geological Society of America; honorary member of the American Institute of Mining Engineers; associate of the American Academy of Arts and Sciences at Boston; member of the Moscow Imperial Society of Naturalists, of the Sweden and the Neuchâtel Academies of Science, and of the Lille Academy of Natural Science; associate member of the Geological Society of the North at Lille, and foreign member of the Geological Society of London. In 1878 the degree of LL. D. was conferred upon him by Trinity College, Dublin.

Lesley in his Old Age.—Apart from the depression that resulted from overwork, Lesley carried much comfort into his old age. Enthusiasm for his science remained undimin-

ished; his eager interest in many other subjects continued unabated. New happiness came to him in the birth of his daughters' children, while the happiness of his own home life went on undimmed. He could reply, when his juniors thought him old:—"Yes, but you young people do not know what old age is." "It is a mistake," he wrote when nearly threescore and ten, "to say that poetry is married to youth," for he knew that "the true poet is the old man, who has seen everything, tried everything, felt every emotion, drunk the wine of many vintages, travelled through many valleys and stood on many peaks, until the beauties of heat and cold, light and darkness, land and sea, have photographed themselves in the album of his memory, and arranged the full score of a divine opera for the whole orchestra of his nature. Every commonplace fact has been sublimated for him into a symbol. The universe resounds with concerted music. The difference between space and infinity, time and eternity, has vanished; yea, the difference between the real and the ideal, the material world and the great spirit which evoked it from his own thoughts. The poet is created when he sees God everywhere in everything. Man shall not be excused for growing old; his proper function is to grow poetical; and the very essence of the poetical is benevolence. It is beautiful to see in the lives of Emerson and Longfellow how lovely and lovable they grew as they became old. They ceased to write; but when their words fell away from them, it was like the shedding of the leaves in autumn, leaving the marvelously beautiful forms of the trees in full view against the evening sky."

There were times after his seventieth year when, for months together, he carried on his work steadily and with enjoyment, greatly cheered and supported by the approval with which the Survey reports were received. Even when his health was seriously failing, he was sometimes like his younger self, all smiles over some fine illustrations that he had drawn; but after 1893 his work decreased and his letters ceased; for some years there is no record: he was literally worn out.

Shortly before the end of the century Lesley left his Philadelphia home and went to Milton, the same Milton near Boston where he had preached fifty years before and which he loved

so much, and there, in a pleasant house that had been given to his wife by her relatives a few years before, tenderly cared for by children, grandchildren, and many friends, the devoted couple passed their last years together. Their lives of faithful work were over; they quietly waited and passed away—he on June 1, 1903, and she in January, 1904.

Lesley was in his prime from his thirty-fifth to his sixty-fifth year, or from about 1855 to 1885. At the beginning of this period he had, after an earlier time of changing occupations and narrow means, established himself by hard work as the leading geological expert of Pennsylvania; and as a result plenty of professional employment soon followed the hard times of '57. His further advance was assured and uninterrupted. He was chosen by the self-ordained *Parcæ Scientiæ* of that period one of the fifty original members of the National Academy of Sciences in 1863; during a stay in Boston to deliver a course of Lowell Institute lectures in 1866 he was welcomed by the leading literary and scientific men of that then intellectual city; he was made professor of Geology and Mining, and dean of Town Scientific School in the University of Pennsylvania in 1872 and '75; in 1874 came the crowning event of his life: his appointment as director of the Second Geological Survey of his State, in the establishment of which he had been a leading actor, and for the leadership of which he had no competitor. But his constitution, never robust, had already weakened; not long after he was placed in charge of the Survey his health began a long decline. In 1883 he withdrew from University duties, and thereafter remained engrossed in Survey affairs until they overwhelmed him. He retired from all work in 1893.

How curious was the play of circumstance before Lesley definitely made geology his career! As a devout young student, intending to prepare for the Presbyterian ministry, his first acquaintance with geology was formed when a search for better health led him, altogether untrained in the science, to undertake field-work in the anthracite coal region as assistant to H. D. Rogers in the first Geological Survey of Pennsylvania.

Strengthened by two years out doors (1839-'40) he entered upon his chosen study of theology, but with an undercurrent of geology, for three years at Princeton (1841-'44) and one year in Germany; and then, having been licensed to preach, he spent two summers (1845-'46) in the forest counties of Pennsylvania, distributing tracts and exhorting the country folk in their secluded villages. Had his strength allowed him to continue in this dutiful task, at one time so dear that, while immersed in it, he felt that there was nothing else worth living for, he might naturally enough have found a mate in the household of one of the well-to-do farmers or ironmasters, who became so earnest and solemn when he laid down their duty, even though topics of high morality were not their usual subjects of conversation; and in that case the forest counties would have retained, for a time at least, his enthusiastic services, and the geology of the State would have had to wait for another master. But again his health was endangered and again a geological opportunity was opened by Rogers, this time (1846-'47) on Pennsylvania map work in Boston, where new associations in new surroundings, till then as unsought as unexpected, exercised a powerful influence on all his future. Once more, after his geological task was finished, he turned to preaching, now in a Congregational pulpit near Boston (1848-'50); and as a further result of his sojourn away from home he married a New England woman of rare quality, who gave him thenceforward devoted support and elevating companionship. With little delay his earnest, independent, uncompromising spirit was so far liberalized by the radical atmosphere in which he found himself, that the Association of his church refused (1850) to ordain him; thereupon, after preaching a short time longer, he for the third time turned to geology under Rogers and for a year (1851) worked on private surveys of anthracite coal lands in Pennsylvania. In the following year, after much discouragement, he secured employment for himself on coal-land surveys, and from this time forward geology was his life work; but religious matters always retained a strong hold on him.

His tasks were laborious; he plunged into them with whole-souled energy and soon developed remarkable expertness. The

mental exuberance of his earlier years continued into middle life. His versatile interests always provided him with happy distraction, whenever a spare hour allowed him to observe, to think, or to write. He became enormously informed by recklessly wide reading; and as his memory was extraordinarily retentive, his varied information was immediately ready for use; he was therefore always an interesting, even if sometimes a dominating, talker. Two habits formed in his early manhood still controlled him: one, a sententious habit of thought and expression, which must have come from his experience as a preacher; it led him to remain long afterwards on familiar terms with universals and unknowables, and to exalt and glorify the common events of life, with equally confident assertion in both cases; the other habit was that of doing all sorts of work himself, because as a young man he had been unable to engage any one else to work for him; a habit that he was loath to give up even when enlarged responsibilities and increased means should have prompted him to leave many tasks to his juniors; it was as if he could not bring himself to feel that they could do the work as well as he could. He was always a man of deep affections and reverent nature, strong opinions and extravagant enthusiasms, some of which, long persisted in, carried him to fantastic extremes. He was a genuine lover of all the greater fine arts, and well practiced in two smaller ones: clear, forcible writing and simple but effective drawing. His journals of 1844 in Europe were filled with sketches; his long family letters were not infrequently ornamented in the same way, though his usual avoidance of narrative and his indulgence in moral reflections and rhapsodies with his correspondents gave him when at home relatively small need of graphic aid. He was an untiring worker, frequently to the point of injuring, and at last to the extreme of ruining his health; indifferent to worldly success and social station, warmly sympathetic, unselfishly devoted to all good and generous causes; an outspoken advocate of the abolition of slavery even during the critical years just before the War of the Rebellion, when the avowal of such principles in Philadelphia placed a man close to ostracism by the orthodox. He was sometimes mistrustful of his powers, and often spoke and wrote with a turn towards melancholy,

especially in his later enfeebled years; yet when in good health he was a cheerful optimist. Depressed as he was repeatedly by contacts with rough Americans in the concrete, he always maintained their virtues in the abstract.

It is indeed curious to learn that this man, so marked an individual in his peculiarities, so complex in his interests and sympathies, so full of religious feeling, so largely an idealist, so ready to carry his deductions far beyond his facts, so deeply impressed by his momentary surroundings, so adventurously vehement in one opinion at one time and so insistent on its opposite at another, himself so mistrustful of business ventures and so free in expressing a scornful pity for those whose lives were given over to mere money-making, was nevertheless the trusted adviser of practical men. This must have been because the deeper currents of his thoughts ran on geology through all his maturer years, and because he held himself close to the truths of his science by repeated contacts with the facts of the field; and above all because of his laborious faithfulness to duty, his courageous independence, and his unswerving honesty. Should an inquiring traveller wish to know what Americans are like, he should be told that they are of too many diverse types to be generalized in one; but should he wish to know one of the types, let him study the life and work of Peter Lesley, a noble type represented by a single individual.



Alfred M. Mayer -

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OF

ALFRED MARSHALL MAYER

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BY

ALFRED G. MAYER AND ROBERT S. WOODWARD

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ALFRED MARSHALL MAYER.

ALFRED MARSHALL MAYER was born in his father's house on Franklin street, then the fashionable quarter of Baltimore, on November 13, 1836. His father, Hon. Charles Frederick Mayer, a Senator of Maryland, was attorney for the Baltimore and Ohio Railroad and other corporations of that day, and as a lawyer had for years maintained one of the most successful practices in the city.

Since the mental traits of men of science are apt to become well known, it is of interest to trace their probable origin in ancestry, and in this case the quest seems not wholly fruitless. On his paternal side, the family which was of remote Swiss origin, had for centuries been citizens of the free city of Ulm, in Württemberg, and the records of their births, marriages, and deaths appear in the registers of the ancient Lutheran Münster of this quaint old city by the Danube. In all this long record there is nothing either of genius or of degeneracy, for generation after generation pursued the even tenor of its modest way, respected, and at times even honored by its fellow-townsmen as presidents and captains of their guilds, but all the while unknown beyond the narrow confines of the medieval walls of Ulm.

Thus it was when Christian Mayer, a grandfather of the subject of this biography, emigrated to Baltimore in 1784, and having inherited a fortune, large for the day, from his uncle and father, became a leading East Indian ship owner and merchant, at the same time serving his king as Consul General of Württemberg in the then newly created United States. Sober, honest, industrious, well educated, but unimaginative, conservative, and in all things in accord with the tradition of his Lutheran extraction was Christian Mayer—a man among whose hundreds of carefully copied letters not one touch of humor appears. Fortunately, however, he married in America a woman in whose veins there flowed the blood of the Huguenot, and like a ripple over a placid lake there came a change in the spirit of his descendants.

Her son, Brantz Mayer, uncle of the subject of this biography, was a man of wide culture, known in his day as a writer upon Mexico and upon the slave trade, but now chiefly remembered as the founder of the Maryland Historical Society. Charles, the father of Alfred M. Mayer, was noted for his knowledge not only of law but of many unrelated subjects; but his high reputation as an attorney rested upon a remarkably analytical ability, which enabled him to win success in presenting intricate cases before justices of the supreme and other high courts. As an orator facing an ordinary jury he was somewhat out of his element, for in thought and speech he was apart from the masses of his time, and while few were more widely known for their charity and kindness of heart, yet there was to be observed in him that aloofness of the student which caused him to look upon the average of humanity as hardly of his kind, while on the other hand he cherished and maintained the warm regard of that small circle of congenial and cultured spirits in whose companionship he found his highest pleasures.

Eliza Blackwell, who was the second wife of Charles F. Mayer, became the mother of Alfred M. Mayer. She was of Scotch-Irish blood, highly connected in the land of her ancestors, and her charms were those of the gentlewomen of the Emerald Isle. Endowed with a courtly grace and blessed by an impulsive, kindly heart, she felt rather than reasoned, loved rather than analyzed, and in the full enjoyment of the present she gave perhaps too little thought to the possibilities of the future. In common with the custom of the "Old South," the sons were placed each in his separate suite of rooms in the top story of the great rambling homestead, and thus they grew into manhood, each in his own inevitable way, perhaps too little heeded by parents or elders.

This peculiar system, or perhaps lack of system, had, however, one cardinal virtue to recommend it, permitting as it did free play to the development of individual characteristics. Thus Frank busied himself with art, and his room became a studio, while his younger brother, Alfred, plunged into the pursuit of all things scientific, from collections of insects to the study of the stars.

The children were sent at first to private schools and later to the conveniently situated Catholic College of St. Mary's, in Baltimore. Science had no place in these schools, and from the first Alfred was in rebellion against a system of education which forced him into endless translations of ancient languages and obliged his serious attention to the miraculous lives of the saints. His father had cherished one dominant idea respecting the son's career: he was to be a lawyer; hence his names, Alfred, the great lawgiver, and Marshall, the greatest expounder of the law in America. Finding that law had no place on the horizon of his son's thought, the father largely lost interest in the task of his higher education as something all but foredoomed to failure.

Thrown back upon his own intellectual resources, the son, whom others could not teach, trained himself. His rooms became filled with scientific apparatus of his own making, while assiduously, intensely, and quite alone he laid thus early the foundations for his elevation to science. It was fortunate that at about this period Prof. Joseph Henry, Secretary of the then newly founded Smithsonian Institution, visited Baltimore and, being the guest of Charles F. Mayer, was induced to ascend to the attic to see the apparatus. A friendship which endured throughout life arose between the great student of nature and the boy. It was through Henry's influence that Mayer secured the collegiate positions which enabled him to pursue the subjects he loved to investigate, and throughout the best and most fruitful years of his life Henry remained the master upon whom he looked and of whom he spoke with reverence as "his father in science."

The novice who struggles against his environment seems doubly unfortunate if surrounded by evidences of affluence. Poverty at least grants its freedoms, for there is nothing of social prejudice to live down; but the engineering sciences in which this boy delighted held but a poor place in the respect of the aristocratic South. Self-absorbed, eccentric, and disapproved of as seeking a career in which even success meant failure, he early learned the strength of his own unaided personality and with the knowledge he acquired self-reliance; for, after due deliberation, his father decided against sending so

strangely unconventional a son to college—a decision which strikes us as the more remarkable in that Charles F. Mayer was himself a graduate and a trustee of Dickinson College and his house was a center for all that was intellectual and cultured in the Baltimore of those days.

Thus in an atmosphere of opposition or indifference, which certainly developed character, even if it left its mark of sadness through many a year, the boy developed into that little-to-be envied individual—the self-made man. The first lecture upon Physics which he ever heard was one he gave himself when Assistant Professor of that science in the University of Maryland, at the age of twenty-one. Into broad fields of study and research his love of truth had led him, for he was a born experimenter and his mind, for so keen an enthusiast, was remarkably analytical; but in special departments, such as mathematics, his knowledge remained hardly adequate for the bold tasks of his life-work and, in common with other self-made men, his equipment, although highly efficient in many essentials, was somewhat weak in others.

Inevitable as this “one-sidedness” is in those who train themselves, yet in his case it seemed accentuated by the very intensity of his character, for in him the cautious, philosophic southern German seemed to struggle against the impulsiveness of the Celt and the generous altruism of the Huguenot. His indeed was a nature difficult of analysis, for there was often war within him, as if between ancestral strains whose ideals clashed one against the other. Yet to just such unbalanced characters the world owes most that is significant in the history of its progress.

At the early age of sixteen he broke from the tradition of his caste, and we find him in “overalls” laboring as a machinist in the workshop of a local engineering firm. One is under the impression that these days of new-found freedom were among the happiest of his life. He delighted in accurate craftsmanship, and soon acquired remarkable skill in turning and in chipping to a true surface the valve-seats of engines. After two years of this excellent experience, we find him acquiring a considerable local practice as an analytical chemist and serving as expert to various manufacturing and mining corpora-

tions, and, among other things, he found that the red lead then commonly used in glazing pottery was highly poisonous.

It was then, when only nineteen years of age, that he published his first scientific paper, which attracted sufficient attention to cause its republication in Germany. It was upon a new carbonic acid apparatus and appeared in the *American Journal of Science*, volume 19, 1855. Two years later this was followed by another in the same journal upon the use of fine rods of drawn glass in estimating minute weights down to $1/1000$ milligram. For the following ten years he published no more papers, but devoted his energies to perfecting his education and to the exacting duties of a teacher. In 1857 he gave lectures upon Physics and Chemistry in the school of science and arts of the University of Maryland, succeeding Dr. John H. Alexander, who went to Europe in the endeavor to bring about an international coinage. But Baltimore was becoming too narrow a field for the young man's endeavors, and in 1858 he secured the appointment to the newly founded Charles professorship of Natural Sciences in Westminster College, Fulton, Missouri. He has left an interesting account of the long, tedious railway journey across the plains when the nights were weirdly lighted by the comet of that year. Out in this little frontier college of 150 students he soon established courses in physics, chemistry, and zoölogy, which, to judge by his prospectus, must have been unique; for at a time when dry, textbook instruction was the rule he declared that no adequate book on physics existed in the English language, and based his teaching upon lectures illustrated by numerous experiments. His skill as a manipulator of instruments was extraordinary, and it has been said that never were his class-room experiments known to fail. In his youthful enthusiasm he was obliged to resort to many makeshifts to illustrate the principles of science, and once the bursting of a defective retort seriously injured his left hand by flooding it with fused chlorate of potash.

But the dark shadow of civil conflict was then brooding over the land, and many of the bright young men for whose intellectual welfare he labored so earnestly were soon to fall in final sleep upon many a bloody battlefield. The young professor also caught the contagion of the war, for in one of his letters

he declares his intention of returning at once to serve in the artillery under the "old colonial flag of Maryland." Upon his return, however, he found the family councils set decidedly against him. His father, an abolitionist, who had freed his own slaves, was Union in sentiment, as was also his uncle, Brantz Mayer, then serving as Brigadier General of Maryland Volunteers, and afterward as an officer in the regular army, while one of his brothers had already entered the United States Navy as a commissioned officer.

Moreover, Maryland refused to secede and there was no "colonial flag" to serve. It seems difficult at this late day, when so many issues once vital have passed into the oblivion of forgetfulness, to grasp the logic of his view; but as one whose country declined to call him, he left Maryland in 1863, crossed the ocean and enrolled as a student in the University of Paris. Here Regnault, that prince of experimenters, was in his prime, and his lectures produced a deep and lasting impression upon the young American student, although he took courses in physiology and chemistry as well as in physics. The superficial glory of the third Empire was at its height and the activity and brilliancy of Paris charmed and fascinated him, causing him in after years often to long to return to this beautiful city, where these years of his fullest joy were spent. But these potentially fruitful student days were of brief duration, for in 1865 he returned to America without having taken a degree and became Professor of Physics and Chemistry in the Pennsylvania College of Gettysburg.

This college was a small one and had suffered seriously through the incidents of the Civil War, and apparently the labor of reconstruction and teaching prevented his indulging in research, for his only writings of this period were a translation of Delaunay's "Essay on the Velocity of Light" and an article upon "God in Nature," in which he maintains that the inspired character of the Bible is evident through its essential unity—a conclusion to which he could not have subscribed in later life, when he had lost faith in the tenets of any orthodox religion. The truth was that in these years he was busily engaged in perfecting his education and also in the preparation of his "Lecture Notes on Physics," which were published in

the *Journal of the Franklin Institute of Philadelphia* in 1868 and appeared also as a separate book. That his services to the Pennsylvania College were not unappreciated is attested by the fact that in 1866 this institution conferred upon him the degree of Ph. D., this being the only collegiate degree he ever received.

His energy and ability began to attract attention, and in 1867 he was called to the Professorship of Physics and Astronomy in the newly established Lehigh University. At this university, for the first time in his life, he became master of a well-equipped laboratory, and under the stimulus of favorable surroundings he plunged enthusiastically into experimental researches, especially in the fields of electro-magnetism and astronomy, in recognition of which he was elected a member of the American Philosophical Society of Philadelphia, which brought him into intimate association with such men as Cope, Leidy, and Dr. Henry Morton. At this time, also, Mr. Robert H. Sayre, one of the trustees of Lehigh University, provided the means to erect and equip an astronomical observatory, and through the use of its six-inch equatorial Mayer observed and described a peculiar elliptical marking upon Jupiter and made studies of aurora; but the equipment of the observatory was too meager to permit of the prosecution of any really important work.

In the field of electro-magnetism he describes at this time a method for determining the relative electrical conductivity of various metals, the plan being theoretically interesting, but without practical value; also during a visit to Trenton and Niagara Falls he found that on misty days the water was heated by the arrest of motion after the descent, as one would expect in accordance with the first law of thermodynamics. If the atmosphere were dry, however, the evaporation more than offset this heating effect. He also devised a method whereby the directions of magnetic lines of force could be fixed, the plan being to form them of iron filings upon a glass plate coated with shellac and then melt the shellac, causing the filings to adhere to the plate. Professor Coffin, Superintendent of the United States Nautical Almanac, organized an expedition to study the solar eclipse of August 7, 1869, and Mayer was chief of the section which took photographs of the sun

during the eclipse, at Burlington, Iowa. By means of an ingenious mechanism, supplemented by a well-devised system of manipulation, he succeeded in taking 41 perfect photographs of the eclipse, four being of totality, the exposures being about .002 second. This, with the old-fashioned wet plates, was considered to be a remarkable achievement and his published report attracted much interest.

He gives a graphic description of the eclipse: "A minute or two before totality the sky grew ashen, or rather leaden, in hue, and Venus and Mercury came out, shining beautifully on a ground of bluish gray. I thought I saw a flashing, twirling motion in the corona or in the last rays of the sun. Moths and insects in profusion passed between me and the sun, while a flock of birds, with troubled, irregular flight, seemed seeking cover from the unnatural gloom which surrounded them. A low moaning wind now sprung up, and the whole atmosphere seemed filled with a leaden-colored vapor, and I experienced an indescribable feeling of oppression when I tapped the trigger; and from that instant until the sun reappeared I had nothing but an instrumental consciousness, for I was nothing but a part of the telescope."

As is often the case in newly organized educational institutions, a certain degree of friction soon manifested itself between the governing body and the faculty of the college; and Mayer's life at Lehigh was not wholly free from the somewhat harassing effects of this period of adjustment, and this rendered doubly welcome the offer by President Henry Morton, in 1871, of the chair of Physics in the newly established Stevens Institute of Technology at Hoboken, New Jersey. This position, as senior professor of the faculty, he was destined to retain throughout the remaining twenty-five years of his life, and it is for the researches accomplished during the first nine years of this period that he is chiefly known and recalled.

At Stevens Institute he became director of one of the best endowed and adequately equipped laboratories of the period, and it was here that he commenced the series of experiments upon sound which made him clearly the leader in this field among American men of science. This was a period of activity so intense that it could not last for long. Throughout the days

and far into the morning hours he worked, and yet found time to enjoy the social cheer of the Century Association in New York, of which he was a newly elected member. Apart from his work in research, he wrote three books of popular interest: "The Earth a Great Magnet," "Sound," and "Light," the last being in collaboration with Charles Barnard.

In the "Earth, a Great Magnet," he presents an excellent résumé of the subject of terrestrial magnetism, illustrated by many striking experiments, some of which were performed with the great electro-magnet of the Stevens Institute Laboratory, then believed to be the largest in the world. In this work he describes a new form of projection galvanometer, which was a decided improvement over previous forms and has been widely used in physical laboratories.

His book called "Sound," published by Appleton, is intended for beginners, and as such it remains today one of the best in the English language, abounding as it does in simple but ingenious experiments, in the devising of which its author was unsurpassed. Mayer also wrote a remarkable and well-illustrated series of articles in the "Scientific American Supplement," upon the "Minute Measurements of Modern Science," in which he maintained that "every instrument of precision contains within itself its own means of adjustment."

Several of the more important articles in Johnson's and in Appleton's Encyclopedias, such as those upon sound, the microscope, and the spectrum, are from his pen, and in the "American Journal of Science" and in the "Popular Science Monthly" he wrote articles of general interest upon the history of Young's discovery of his theory of colors, "Flying Machines and Penaud's Artificial Bird," "Marey's New Results in Animal Movements," "Edison's Talking Machine," and on "Manometric Flames," by Dr. R. Koenig, of Paris.

But the reputation of a man of science must rest, in the last analysis, not upon his skill as a popularizer of the knowledge of his day, but upon the significance of that little which he has himself discovered and given to the world; and, judged by this higher standard, the efforts of this most active period of Mayer's life, between 1871 and 1880, were more than commonly successful. It is for his discoveries in acoustics that he

is best known, the results being presented in ten articles, published in the "American Journal of Science" between 1872 and 1896.

Helmholtz had discovered that a certain number of beats per second between two tones produce in the ear a maximum dissonant sensation, while a greater number will gradually blend into a smooth, continuous sound; and he also found that the sensation produced by sounds of low pitch remain longer upon the ear after the actual sound has ceased than do sounds of high pitch. Helmholtz even attempted to give a quantitative expression to this law, but failed, owing to the extreme difficulty and patience involved in the research. In 1874, and again with improved apparatus in 1894, Mayer approached this subject from the quantitative side. Moreover, his results were supported, in 1875, by the observations of Madame Emma Seiler, who had assisted Helmholtz in his studies of sound and who was noted for her acute musical perception; and in later years Rudolph Koenig also confirmed Mayer's results, which may thus be considered to be well established and have been accepted by Lord Rayleigh in his standard treatise upon sound.

Mayer's earlier method consisted in interrupting the responses of a resonator by means of a perforated rotating disk which periodically permitted and shut off its sound. Later he improved the arrangement by permitting the resonator to respond continuously, while the revolving disk merely interrupted the sound which came from it. He was thus enabled to measure the time during which the after-sensation of a sound does not appear to diminish in intensity, and he found that if we call this time D , the formula for N vibrations per second becomes:

$$D = \left(\frac{33000}{N + 30} + 18 \right) 0.0001$$

This represented the law for his own ear, but the constants differ for different ears, although the form of the equation remains that of the hyperbola for sounds between 64 and 1,024 vibrations per second. This formula has commonly been referred to as "Mayer's law." Its establishment cost its discoverer many months of patient effort, the strain of which was so

severe that the hearing of one of his ears was permanently injured.

The establishment of this law led to further studies, and he soon found that the greatest dissonance between two tones is produced by about $\frac{4}{10}$ the number of beats required to give a continuous sensation. Moreover, the smallest consonant intervals between two tones, or the smallest number of beats between the two tones which produce a resultant blended tone, follow Mayer's law with a sufficient degree of accuracy for tones between 128 and 2,806 vibrations per second. The law does not apply to Sol, of 96 vibrations per second, and Koenig found that there are no consonant intervals for tones of 64 vibrations per second or less.

The most interesting deduction from this law was Mayer's discovery that a sound of low pitch can, if intense, obliterate the sensation due to one of high pitch, but high-pitched sounds, no matter how intense, cannot obliterate those of low pitch. He also found, in 1894, that one can hear beats between two tones, both of which are too high in pitch to be heard; but in this he was anticipated by Koenig, who used tuning-forks, while Mayer used "bird-call" whistles.

A study that attracted much attention and gave rise to some amusement among the public was his observation of the supposed auditory organs of the mosquito. He found that certain of the fibrils of the plumose antennæ of the male mosquito were set into most vigorous vibration by tuning-forks of Ut_3 or Ut_4 , ranging from 256 to 512 vibrations per second, while other tones between 128 and 1,024 vibrations per second were less effective in causing the fibrils to vibrate. In any case the fibrils vibrate most actively when they lie perpendicular to the direction whence comes the sound, and this probably enables the male mosquito to direct his course toward the female, for when both antennæ are equally affected his body points in the direction of the source of sound. As long ago as 1855 Dr. Christopher Johnson, in the *Quarterly Journal of the Microscopical Society of London*, had formed the opinion, based upon anatomical facts, that the fibrils of the antennæ are the auditory organs of the mosquito, and he drew the inference that the fibrils of the male responded to the sounds produced

by the female, although he appears not to have observed the vibration of the antennæ. The studies of Johnson and of Mayer suggest, but do not prove, that the fibrils of the antennæ are auditory organs, for neither investigator observed the behavior of the free male mosquito in the presence of the sounds to which its fibrils covibrate.

In his study of human audition Mayer found that if the base of a tuning-fork, such as Ut_3 , be pressed against the zygomatic process close to the ear, one hears not only the proper tone of the fork, but also its higher octave, and this led him to conclude that when simple vibrations impinge on the ear the tympanic and basilar membranes vibrate twice, while the hair-cell cords in the organ of Corti vibrate only once. Also, these hair-cell cords are supposed to be the covibrating bodies in the ear whose movements lead to the perception of the pitch of sound.

In January, 1876, Mayer found that the pressure on the closed end of an acting resonator is greater than at the open end; hence the resonator tends to be repelled. Thus four such resonators attached to the ends of a pivoted cross may be made to rotate. Dvořák, of Angram, Austria, had invented the same apparatus in 1875; thus this "sound mill" was devised independently by the two investigators, Dvořák's invention taking precedence over Mayer's.

In other researches upon sound, Mayer gave an experimental demonstration of Doppler's principle, showing the influence of motion upon the apparent pitch of sound, his method being closely similar to those previously adopted by Koenig and by Radau. Using Koenig's manometric flame, he devised an experimental method for detecting the phases of vibration and of measuring the wave length and exploring the form of the wave surface in the air surrounding a sounding body, and this led to the invention of an acoustic pyrometer for measuring high temperatures, which has proven of practical value in certain researches, its readings within certain limits being comparable in accuracy to those obtained from the air thermometer.

Mayer was thus the first to accurately and quantitatively determine the effect of temperature upon the rate of vibration of tuning-forks and the wave lengths to which they give rise. He also experimentally determined the relative intensities of

sounds, and measured the capacities of various substances and gases to reflect and to transmit sound. He illustrated by ingenious experiments Fourier's theorem as applied to the decomposition of the vibrations of a composite sonorous wave into its elementary constituents, and also to an illustration of Helmholtz's hypothesis of audition. By stretching a number of silk fibers, one end of each of which was attached to the prong of a tuning-fork, while the other end was made fast to a loose inelastic leather membrane mounted in a frame near a reed pipe, he succeeded in one and the same experiment in demonstrating both the analysis and synthesis of a composite sound.

He also determined that the energy per second given forth by an Ut_3 fork of 256 vibrations per second was sufficient to lift one gram through a height of 10 centimeters, or about one-millionth of Joule's unit. This result was attained by measuring the relative intensities of the sound when its movements were partially damped by means of India rubber, thus causing the rubber to rise in temperature. Concerning this demonstration, Prof. Le Conte Stevens has remarked: "The difficulties attendant upon such an experiment are very great and no one but an experimentalist of exceptional skill and patience would be apt to undertake it."

His last research in acoustics, published in 1896, was upon the modulus of elasticity of aluminum as determined by its sonorous properties. In prosecuting this study, he went to Paris and enjoyed the advantages of working with the great "tonometer" of his friend, Rudolph Koenig, for nowhere else in the world could one find apparatus for determining the pitch of pure sounds with sufficient accuracy for the requirements of this research. He found unexpected variations in the modulus of elasticity of aluminum, and thus for sonorous purposes it is inferior to steel. The method is well adapted to determine the *variation* rather than the absolute value of the modulus of elasticity.

Mayer's experimental researches in the determination of the forms of acoustic wave surfaces led to the invention of an instrument which he called the topophone and which was designed to determine the direction of the source of sound. The apparatus consisted of two resonators, mounted at the ends of

a rigid rod, the axis of each resonator being perpendicular to that of the rod, and the length of the rod being less than that of a wave length of the sound to which the resonators were in tune. The openings at the backs of these resonators were connected with rubber tubes, which were joined to a single tube in such a manner that one of the branches was longer by one-half the wave length of the sound than the other. Thus when the receiving openings of both resonators faced the source of the sound, interference was produced and the response reduced to a minimum. By means of this apparatus, the source of a sound from 100 to 1,000 feet away could be determined to within about 1.5° angular measure, while even an inexperienced person could determine the direction of a fog-horn within 10° when from 4 to 6 miles away from the source of sound.

This instrument was designed to enable ships to determine the direction of fog sirens, but as the tones of sirens are complex and no two give the same fundamental note, it would be necessary to adjust the resonators to each special case, although this could perhaps have been done and would indeed have provided a means of discovering not only the direction of the fog-horn, but the identity of the siren itself; yet Mayer never perfected his apparatus and it has been of no practical value.

In fact, despite the fact that he was a mechanician of rare skill and had few equals as an experimentalist, his interests were in theoretical and not in applied science. In England or in Germany his discoveries would have met with greater public appreciation than in America, where science, especially in his day, was esteemed in proportion as it filled a want or led immediately to the rise of material progress. He was a man of ideas rather than of action—a thinker, not an organizer—and all the wonderful energy of his enthusiastic, almost boyish nature seemed but to minister to the graces of his mind. A versatile conversationalist and charming story-teller, he combined in rare coördination the thoroughness of the Teuton with the fine appreciation of the Huguenot and the humor of the Celt.

Whatever he was engaged upon was done with his whole heart; everything that interested him became a "hobby," to the exclusion of all else for the time; and so true was this that

even science could not claim his constant interest, for during the best and most vigorous years of his life, between 1881 and 1889, he was so enthusiastic over shooting and fishing that he all but neglected research and published only three short papers.

It was during this period that he became deeply interested in the discoveries relating to the condition of early man in the Stone Age in Europe, and he acquired a respectable collection of their implements. A piece of elk horn from the caverns of France interested him greatly, for upon it was a rude but effective drawing representing prehistoric hunters engaged in the chase of the reindeer. Several of these animals are shown in active flight, while one lies upon its back with its legs held stiffly upward. One day, however, an explanation of the matter came clearly to him, when his guide in Canada described the Indian custom of propping a slain deer upward with blocks of snow so that its legs might project above the drifts, and thus the quarry could be found upon the return of the hunters.

But to return to the researches of his most active years, between 1871 and 1880, while his major effort was in the theoretical side of acoustics, yet he conducted some interesting experimental studies upon magnetism, electricity, heat, and light.

We have already mentioned his remarkable general treatise upon "The Earth, a Great Magnet," but the most beautiful experiment he ever performed in the domain of magnetism was upon floating magnets. He magnetized a number of needles and mounted them upon corks, so they could be partially immersed within water, with their south poles upward. Then, when the north pole of a powerful steel magnet was held vertically above them, the mutually repellant floating needles were made to approach and arrange themselves in definite figures, which suggested the manner in which atoms of molecules may be grouped in the formation of definite compounds.

Thus, three needles must set themselves at the vertices of an equilateral triangle; four must arrange themselves at the corners of a square; five may either form a square with one in the center, or set themselves into a pentagon, and six may form a pentagon with one in the center, or arrange themselves three on a side in the form of an equilateral triangle. Where there

are two or more forms of arrangement, some of these are more stable than others, and only the most stable form the nuclei, or central figures, of the higher combinations made from nine or more needles, for Mayer discovered that the configurations of the floating magnets may be divided into primary, secondary, tertiary, etc., classes, and the stable configurations of a lower class form the nuclei to the succeeding ones.

Thus the configuration of nine magnets begins the secondaries by having two needles for its nucleus, with seven forming a polygon around them. The other secondaries of from 9 to 19 magnets have the stable primaries from 2 to 8 for nuclei, and the tertiaries have the stable secondaries for nuclei, etc.

The experiment appears to furnish an optical analogy of molecular structure, expansion on solidification, and isomerism, and Sir William Thomson (afterward Lord Kelvin) was greatly delighted with it, and expressed his pleasure in an article in "Nature" of May 2, 1878, in which he states that Mayer's experiment had given a perfect mechanical illustration of the kinetic equilibrium of groups of columnar vortices revolving in circles around their common center of gravity, and had thus thrown light upon some problems respecting the constitution of matter.

Mayer's improvement in the laboratory form of the reflecting galvanometer we have already referred to, as also to his method of fixing and photographing the spectra of the magnetic lines of force. He also studied the effects of magnetization in changing the dimensions of iron and steel bars, using for this purpose the very sensitive reflecting comparator invented by Joseph Saxton; and he discovered that if a certain elongation is obtained by a strong electric current, this elongation tends to maintain itself, even when the current is greatly reduced by the gradual interposition of a high resistance, and remains far greater than would have been the case had the weakened current alone produced the elongation. This condition might be called "magnetic set" were it not for the fact that this term has been used by Joule and others to describe a different phenomenon.

His determinations of the coefficients of elongation and con-

traction of iron when magnetized were published in two papers in the *American Journal of Science* in 1873. In 1872 he made use of Meusel's double iodide of mercury and copper to trace the progress and to determine the boundary of a wave of conducted heat. The color of this substance is brilliant carmine, but it turns to a chocolate brown upon being heated to about 70° C., and then regains its original color upon cooling. He applied this test to the determination of the elliptical contour of the isothermal of conduction in the principal section of a quartz crystal, finding that the major axis was to the minor as 1 to 1.33, and this result is probably more accurate than the previous determination of Sénarmont, who concluded that it was as 1 to 1.31.

In 1874 Mayer described a new and simple method for investigating the oscillatory nature of the electric discharge, using for this purpose a thin, flat disk of lamp-blackened paper, which was rotated rapidly at a known rate between the discharging points of an induction coil. He found that under these conditions the discharge lasts about one-twenty-fourth of a second and consists of showers of flashes and sparks, separated by intervals of quiescence. (A figure of this apparatus is given in volume 3, part 2, of the *Memoir of the National Academy of Sciences*.)

It may seem remarkable that, living at a time when unparalleled progress was being made in the application of electricity to the service of civilization, he should have all but neglected this branch of physics. The truth is that in common with his great master, Joseph Henry, the practical application of scientific principles to useful ends largely failed to interest him. Thus, despite the great advantages he enjoyed as director of the excellent laboratory of the Stevens Institute and the cordial interest and respect which his achievements in pure science attracted, he was somewhat out of his true element in a school of engineering. Nevertheless his almost unrivaled energy and ingenuity as an experimenter won wide recognition. In 1872 he was elected a member of the National Academy of Sciences, and in 1873 he was an associate editor of the *American Journal of Science*. The American Academy of Arts and Sciences of Boston also chose him to membership, as did the American

Philosophical Society, the New York Academy of Sciences, and others in the United States.

In 1873 he visited England and was most kindly received by such eminent men of science as Tyndall, Wheatstone, De la Rue, Strutt (afterward Lord Rayleigh), Spottiswoode, Ellis, Bosanquet, and Lord Ross, and with these and others he formed enduring friendships. It seemed appropriate that when the Century Association in New York gave its farewell dinner to Professor Tyndall at the conclusion of his famous lecture tour of America, on February 4, 1873, Mayer was chosen to issue the invitations and to arrange the seating of the guests, among whom were included the intellectual, social, and official leaders of the nation.

Once again, in 1894, he visited England and attended the Oxford meeting of the British Association for the Advancement of Science, before which he read two papers. In the long years between these visits most of his old friends had departed, and his own youth had fled, and owing to his having for ten years been more interested in sport than in science his name was no longer very familiar to the rising generation of investigators.

This relatively unproductive period of his life, between 1881 and 1889, was ushered in by a study of the velocity of shot, upon which subject he read a paper before the American Association for the Advancement of Science in 1880. In this research he used a chronoscope, consisting of a rotating cylinder covered with a smoked paper, upon which a tuning-fork made a tracing of its vibrations. A spark from an induction coil perforated the paper at the instant the hammer descended, and also when the shot struck the metal plate that served as a target. His results were a confirmation and extension of those previously obtained in 1875 by Prof. J. M. Rice, of the United States Naval Academy.

Mayer decided, as a result of his experiments, that a ten, or even an eight, gauge gun if of about eight pounds in weight would be the best fowling-piece for upland shooting. As a boy he had been fascinated by shooting and fishing, and now in his middle age the old love of sport returned, and all his mind seemed bent upon perfecting methods and apparatus; for it

was as an experimenter and a craftsman that he delighted in sport, not as an explorer, a lover of the beautiful in nature, or the wild woods, for indeed these things appealed but little to him. Thus it was characteristic of him that, having decided upon the best type of shot-gun, he should proceed to devise the best form of canoe paddle and the best minnow-casting rod; and as a proof of the superiority of the last named, he won the first prize at the Amateur Minnow-casting Tournament of the National Rod and Reel Association in 1884, using a rod of his own invention. He was an excellent shot and noted for his skill in casting the fly and handling a canoe, and as the memory of his achievements in science faded his reputation as a sportsman grew among the members of the fishing and shooting clubs of America.

Thus it was that the Century Publishing Company invited him to edit the superb volume upon "Sport with Gun and Rod in American Woods and Waters," which was published in 1883. To this volume he contributed scholarly articles upon "*The Prehistoric Hunter*," "*On the Invention of the Fishing Reel*," "*Bob White, the Game Bird of America*," "*The Shot-Gun*," "*A Day with the Rails*," and "*The Blow-Gun*." This was his crowning work as a contributor to the literature of sport; but he was also known for many devices of an ingenious character designated to facilitate the comfort or convenience of anglers, and as the inventor of the very successful orange and black trout and bass fly, which he called "The Lord Baltimore."

In 1880 Mayer, when only forty-four years of age, had reached the acme of his scientific fame. In August of this year he read before the American Association for the Advancement of Science his charmingly appreciative memoir of the friend of his youth and manhood—Joseph Henry—a tribute of love and respect to the master whose memory he always cherished and of whom he delighted to speak in terms of gratitude and devotion.

One thinks that his neglect of science for the following nine years was in no small degree due to a sense of intellectual loneliness due to the death of this dear friend and confidant. Moreover, there came upon him, as with crushing force, the

realization of the inappreciation of his countrymen for achievements in pure science, and this deepened the sadness of his intellectual isolation. As a boy he had struggled in vain to win the approbation and esteem of those around him, and the dearest things of all are always those beyond our reach. Thus in a spirit of Epicurean philosophy he turned from his life-work and sank into the amusements afforded by sport. There were intellectual shocks also which men of his generation were called upon to withstand which it is difficult for us in this happier day to appreciate. Darwinism had broken the anchorage of many a faith, and many a ship had drifted aimlessly over the vast ocean of agnosticism. Moreover, acoustics had well-nigh become a finished subject, and Koenig and Mayer may perhaps be regarded as the last great experimentalists upon sound, supplementing the paramount work of Helmholtz and providing the basis upon which Rayleigh developed his mathematical theories. Practical inventions, such as the telephone and the phonograph, had diverted nearly all interest from the purely scientific aspect of the subject, and both Koenig and Mayer died saddened by the thought that they had outlived contemporaneous interest in their field of study.

There was yet another factor which contributed to distract Mayer's attention from science. In 1876 he purchased a country place in Maplewood, upon the slopes of the Orange Mountains, in New Jersey; thus for two hours in every day he was obliged to endure the noise and dust of railway travel in order to reach his laboratory and return to his home; and research becomes difficult when one's time is subject to the autocratic dictates of a time-table. Indeed, it was only in 1891, after he left his country place and returned to Hoboken, that he resumed full activity as an investigator. The very charms of his beautiful country home, with its astronomical observatory and its amateur machine shop, upon the lathes of which he delighted to spend hours in turning, were distractions tending to draw him away from the college laboratory in the Stevens Institute.

Thus it was that between 1881 and 1889 he published only three papers, two appearing in the *Memoirs of the National Academy of Sciences*, namely, one upon a method of measur-

ing precisely the vibratory periods of tuning-forks and determining the laws of their vibration with a view to the calibration of chronoscopes for measuring the velocities of projectiles; and the other, published in 1886 in the *American Journal of Science*, was upon a well-spherometer of his own invention, capable of measuring the radius of curvature of small lenses with an error of not more than $1/125,000$ of an inch. In 1890 there appeared three papers, in which he described ingenious devices for illustrating principles of physics before college classes. These are on a pendulum electrometer for making measurements of static electricity in absolute units, a spring balance electrometer for measuring specific inductive capacities and potentials, and an article in the *American Journal of Science* on a simple method for demonstrating the truth of Ohm's law. He also read a theoretical paper before the National Academy of Sciences upon electrical potential as measured by work. In this fruitful year, 1890, he also published the results of still another research upon the determination of the coefficient of cubical expansion of a solid from the observation of the temperature at which water in a vessel made of this solid has the same apparent volume as it has at $0^{\circ}\text{C}.$, and on the coefficient of cubical expansion of a substance determined by means of a hydrometer made of this substance. This led to the conclusion that the coefficient of cubical expansion for glass is .000025; steel, .000033; copper, .00005; brass, .000056, and zinc, .00009. The accuracy of the method depends upon the exact determination of the absolute expansion of water when heated from $0^{\circ}\text{C}.$

In the following year this latter research was supplemented by a study of the physical properties of vulcanite, the coefficient of linear expansion of which was found to be .0000636 between 0° and $18^{\circ}\text{C}.$, in close agreement with Kohlrausch, while its specific heat was .33125 and its index of refraction was 1.568. As found by Bell, vulcanite readily transmits the rays of dark heat, and Mayer determined that a plate of this substance one-half millimeter in thickness transmits 24 per cent of the sun's heat rays and can be made into a lens to focus heat without light, in which respect it is superior to obsidian. In another investigation upon the illuminating power of flat

petroleum flames in various azimuths, he found that the edge of the flame of a petroleum lamp gives about 37 per cent less light than the flat surface, whereas a flat coal-gas flame gives practically one and the same intensity of light in every azimuth.

After sound and magnetism he was most interested in light, and in 1882 he invented a heliostat, which in place of the usual plane mirror carried a bi-convex lens, which focussed the sun's rays upon a totally reflecting prism, thus giving a condensed beam which could be used to throw upon a screen images of objects magnified about 3,800 diameters. An account of this instrument was published in the *American Journal of Science* in 1897, after the death of its inventor. Between 1893 and 1895 the subject of contrast-color engaged his attention, and he devised a rotating disk photometer for determining the relative intensities of lights of different colors, which gave results comparable in accuracy with the photometer of Bunsen. Also, by means of a glass tube blackened on the outside, he attempted to analyze contrast-colors and decided that the phenomenon is physiological, not psychological or a matter of judgment. He found that complementary contrast-colors are shown by the two halves of an electric spark, the duration of which was probably less than one-millionth of a second, and this leads him to support Hering's rather than the Young-Helmholtz hypothesis of color sensation.

Working in the laboratory of his intimate friend, Professor Rood, at Columbia College, he conducted a research upon the then newly discovered Röntgen rays, finding that the X-rays cannot be polarized by transmission through crystals of herapathite, although this is by far the most powerful substance known for the polarization of ordinary light. He also determined the relative transmission of these rays through aluminum, glass, green tourmaline, herapathite, and platinum in thickness of one-tenth millimeter and one millimeter.

His last research, published in April, 1897, in the *American Journal of Science*, only three months before his death, was upon the equilibrium of the forces acting in the flotation of disks and rings of metal, leading to measures of surface tension. The experiments called for much mechanical skill, delicacy of touch, and dexterity of manipulation, and it seemed

fitting that this last investigation of his should be one in which his distinctive excellence should be so conspicuously displayed. He found, in common with others, that chemically clean metals can be floated upon water, and that the phenomenon is due not to grease or oil, but to a film of air adherent to their surfaces. Experiments with floating disks gave .0791 as the value of the constant of the surface tension of water, while this constant obtained from observation on floating rings was .0809; and, as the mean of the twenty-eight previous determinations by various physicists is .0772, it is evident that Mayer's beautifully simple and direct method is comparable with those of Plateau and Quincke.

As a sequel to this research, he had devised a method for directly measuring the surface tension of films, when the symptoms of an illness from which he had suffered for some months became so acute that he was forced to desist, and he died on July 13, 1897, at his country place in Maplewood, New Jersey.

Biographical notices of him appeared in the *American Journal of Science* for August, 1897; in the *Physical Review*, volume 5, 1897; a more complete account of his life and work, by Prof. W. Le Conte Stevens, in *Science*, volume 6, pages 261-269, 1897, and a contemporaneous biographical sketch was published in the *Popular Science Monthly*, volume 10, pages 230-233.

His friend, Prof. A. W. Wright, says of him: "Professor Mayer's scientific work was marked by strongly characteristic traits. He possessed great ingenuity and skill in construction and a remarkable degree of delicacy and precision as an experimenter, which enabled him to obtain results that will have a high and permanent value in science. Beyond his scientific accomplishments, he was a man of wide and refined culture, with a genial presence and social qualities which made him a delightful companion and endeared him to his friends."

In the more extended notice of Mayer referred to above, Prof. W. Le Conte Stevens remarks: "His restless ingenuity was ever ready for any demand, and his mechanical aptitude was so directed by a delicate esthetic sense that he could never be satisfied with any objective proof which was not neat and simple, as well as adequate. . . . He was conscious of his

skill and naturally took keen pleasure in exercising it successfully. That in so doing he gave pleasure and help to others is manifested by the extent to which his methods have served as models."

He was twice married and was survived by his wife and one son.

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G. W. Hill

**NATIONAL ACADEMY OF SCIENCES
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**BIOGRAPHICAL MEMOIRS
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OF

GEORGE WILLIAM HILL

1838-1914

BY

ERNEST W. BROWN

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GEORGE WILLIAM HILL.*

BY ERNEST W. BROWN.

GEORGE WILLIAM HILL was the son of John William Hill and Catherine Smith, and was born in New York City on March 3, 1838. Both his father and grandfather were artists, and he himself was of English and Huguenot descent. His early education, like that of most of the men of his time in America, gave him few advantages. In 1846, when his father moved from New York to the farm at West Nyack, the country was too busy with material development to produce many teachers who could give any but the most elementary instruction, and the country school which he attended must have been inferior in this respect to those in the larger cities. Even at Rutgers College, in New Jersey, to which Hill was sent, owing to the exhibition of unusual capacity, and from which he took his degree in 1859, the course probably went but little beyond that now found in secondary schools. There, however, he came under the influence of a man whose ideas on education were unusual. Dr. Strong, according to Hill's evidence, believed only in the classic treatises; but little published after 1840 was admitted to his library. Under him, Hill read Lacroix's *Differential and Integral Calculus*, Poisson's *Traité de Mécanique*, de Pontécoulant's *Système du Monde*, Laplace's *Mécanique Céleste*, Lagrange's *Mécanique Analytique*, Legendre's *Functions Elliptiques*. Strong liked to go back for his theorems to Euler, whom he regarded as the greatest of analysts. Hill's sound knowledge of the fundamentals of his subject is doubtless due to this course of reading.

Hill's first paper, published in 1859, when he was but twenty-one years of age, and before he had taken his degree at college, is a half-page note on the curve of a drawbridge. Two years later he showed his capacity in the essay which gained

* The writer of this memoir desires to express his indebtedness to those who have assisted, either by their published accounts of Hill or by letters or in other ways. Due acknowledgment is made below in most cases.

a prize offered by Runkle's Mathematical Monthly for the best solution of a problem connected with the constitution of the earth. "This memoir," says Hill, in a footnote to the reprint of his collected works, "written at the end of 1859 and beginning of 1860, was designed to show how all the formulæ connected with the figure of the earth could be derived from Laplace's and Poisson's equations, combined with the hydrostatic equilibrium of the surface, without any appeal to the definite integrals belonging to the subject of attraction of spheroids. Some of the assumptions are quite unwarranted; nevertheless, I allow them to stand." President R. S. Woodward, who has himself worked much at this subject, says that the memoir is still worthy of careful reading.

In the year 1861 he joined the staff of the Nautical Almanac office, which then had its headquarters in Cambridge, Mass., and for a year or two he worked there, and thus had an opportunity for association with some of the ablest men of the time in astronomical science. But he soon obtained permission to do his calculations at the home in West Nyack, which he never seemed to leave willingly during the rest of his life. It was there that nearly all his best work was done. In fact, he was only away from it for one considerable period, and this is covered by his residence in Washington from about the year 1882 until 1892; even during that time the summers were generally spent in West Nyack.

In the first ten years after leaving college Hill only published eight papers, and none of them deal with celestial mechanics in the modern sense of the term. But from his output after that time it is evident that he had been reading and digesting the newer treatises and memoirs as they appeared. Delaunay's two magnificent volumes on the lunar theory were published in 1860 and 1869, respectively, and the methods of that investigator exercised a fascination over Hill for the rest of his life. He returned to them again and again, and several times not only expressed the opinion that they should be more widely used in planetary problems, but himself outlined ways in which this could be done. But his most important developments on the lines laid down by Delaunay all refer to the moon's motion. He gave the methods which have made them

of practical advantage for the calculation of the effects produced by the planets and the figure of the earth on the moon; this was the step necessary for the completion of Delaunay's work, which had only taken account of the forces due to the earth and sun. The other great lunar theorist of the period, P. A. Hansen, had been explaining his methods for many years before this time, and Hill was probably one of the few men of his age who understood them thoroughly. He does not seem to have been particularly drawn to them, although they are used in his theories of Jupiter and Saturn with but little alteration. It is difficult to find many traces of other influences in his work. His most celebrated memoir, it is true, is based on one of Euler's numerous methods; as he himself tells, but after the start he proceeds entirely on lines of his own devising.

The publications which follow his first attempts during this early period exhibit knowledge of theoretical astronomy and the power to handle large masses of numbers rather than any unusual mathematical ability. In his discussion of the observations of the great comet of 1858, which was undertaken to obtain a satisfactory orbit (1867), he has to deal with 363 places gathered from many sources. As usual with Hill, he does not confine himself to the main point, but discusses systematic errors between the different observatories and those due to the size of telescope used. His final conclusion is that there is no evidence of any force other than gravitation influencing the motion of the comet.

It is probable that his work on this body was responsible for the next three papers—on the reduction of star places, the determination of the elements of a circular orbit, and the conversion of latitudes and longitudes into right ascensions and declinations—or, at any rate, that it drew his attention to these fundamental problems. But he was soon to lay them in the background for more original investigations in celestial mechanics proper. One can see in his published works his gradual approach to this subject. His tenth memoir is a correction to the elements of the orbit of Venus from observations extending over 33 years. It is followed by a derivation of the mass of Jupiter from the perturbations of certain asteroids and the cal-

culatation of an inequality of very long period in the motion of Saturn. Shortly before, however, he had been assisting in the campaign which had started years earlier to get the utmost out of the transits of Venus in 1874 and 1882. Part II of the Papers of the U. S. Commission relating to the transits is by his hand; it consists of charts and tables for facilitating predictions of the several phases at any place on the globe. In these days such work is largely a matter of routine for any efficient almanac office, but at the time of which we are writing much of it had not been systematized and the tables of the planet had not attained to the accuracy which they later received under the administration of Newcomb. And Hill's own work on fundamental astronomy undoubtedly contributed to some extent towards the systemization of the methods generally in use at the present time for the fundamental problems of the astronomy of position.

The active period of Hill's work in celestial mechanics began in 1872. Between that year and 1877, when his two chief memoirs appeared, he published eleven papers on various phases of the subject, besides seven others in pure and applied mathematics and the long transit of Venus calculations already mentioned. Most of them are quite brief and call for no special mention. At this time he seems to have thought that the masses of some of the larger planets could be accurately found by the long period inequalities which they produce in the motions of certain of the asteroids, and he gives some preliminary work in the determination of the masses of Jupiter and the Earth. But there are several objections to this idea. The mathematical difficulties in the computation of the theoretical coefficients, to the degree of accuracy needed, are very great, while the observations themselves must be extended over very long periods. And, further, the later work of Newcomb and Hill himself on the great planets and of others on the satellites have given us far better values for the masses than we could hope to obtain from the asteroids.

A five-page note on the calculus of finite differences is fundamental in the problem of mechanical integration, and it was long afterward used by G. H. Darwin in his work on Periodic Orbits. But it is difficult to follow because of some

confusion in the notation. Several other papers are new demonstrations of well-known formulæ. One memoir, interesting from a historical point of view, consists of some "remarks on the stability of planetary systems." Hill begins by pointing out that the ordinary definition of stability as given in the text-books is quite insufficient for application to planetary systems, and he then proceeds to discuss what the conditions should be. In editing this paper for insertion in his collected works he realized, as we see from the footnotes, that parts of it were rendered obsolete or shown to be erroneous by the researches of Poincaré. Nevertheless, it is a distinct advance on the ideas of the period; errors in accepted views are pointed out and conditions are laid down.

While these memoirs are good and exhibit both knowledge and insight, they could hardly have attracted any special attention outside the small circle of mathematicians and astronomers in America. It was not until he was 39 years old that the first of the memoirs which have given him a permanent place in the history of celestial mechanics appeared. Nearly all his best work was done in the decade from 1875 to 1885, when he was between 35 and 45 years of age. This was probably the natural development for one of Hill's powers, whose early education had been so much inferior in many respects to that which his peers in Europe had received. Even now the opportunities for a man of exceptional powers to obtain full development early are far fewer than those on the other side of the Atlantic, owing to the school and college systems in vogue in this country; in Hill's early years the difference, mainly from lack of well equipped teachers, was far greater. The circumstances under which he lived seem to have contributed to a natural development of his genius, but little affected by external circumstances. From the time he left Cambridge to work at home, probably about 1863, he could have had but little intellectual companionship. And it was twenty years before he went to Washington to live in order to undertake the theories of Jupiter and Saturn. Ten years later he returned to the farm, and lived there until his death. It is worth noting that the time of Hill's most original productivity was during the greater part of the decade preceding his residence in Wash-

ington. Apparently the change affected him very little. He resided in the same boarding-house during the whole time he was there, seeing but few people, and returning to his farm or traveling during the summers.

This sketch of Hill's mental development up to the point where his chief papers were produced is perhaps all too short, but the materials at the disposal of the biographer are scanty: almost nothing is available for the purpose except the few dates and places recording his movements and the internal evidence of his published work. One can only gather that even in his earlier years he lived and worked much alone, gaining his knowledge and receiving stimulus mainly from books. A wonderful calm pervades everything that he wrote. Even after the execution of some analytic *tour de force* like the solution and development of the infinite determinant and the successful reduction of the complicated analytic expression to numbers, there is not the slightest trace of exultation visible. With one case of this the writer happens to be familiar. In the development of the infinite determinant the most troublesome part is the summation of a triply infinite series into an expression involving cotangents and powers of π and consisting of a dozen terms. Two or three times, long after the publication of the result, Hill had been requested to give the method by which he reached it, for the only statement in his paper with reference to the actual work is "The single triple summation may be treated in an analogous manner" [to the double summations]. In a letter dated November 8, 1911, he says: "I spent six weeks of very hard and distracting labor to get the result through the process of summations. I must have done it about six times, scarcely no two being alike in the final result. These results were compared with the check founded on a procedure independent of summation, and [I] found one result which was in agreement with the check. This I had no doubt was right and that the other results were in error, because I had slipped up in the analysis of the triple summation. Had I printed in full the steps of my process it would have added about 12 pages to my paper and the printing would have cost me \$50 additional; hence I limited myself to saying that I had arrived at the result by a method similar

to that employed for the simpler summations. The method used for the check was laborious, but quite plain sailing." The writer succeeded in verifying Hill's printed result for the triple summation, but he was quite unable to do it in a manner which could be called "analogous" to the double summations; other devices had to be employed, and later, in looking over some notes of J. C. Adams, who had also done the summation, it was seen that the latter had been obliged to use similar devices. It would be interesting to know why Hill published this paper at his own expense. Surely the ordinary facilities of the astronomical journals in 1877 were quite equal to printing such memoirs, and Hill was even then not unknown as an able mathematical astronomer. In fact, the paper was reprinted nine years later in the *Acta Mathematica*.

In order that the value of Hill's contributions to celestial mechanics, and more particularly to the lunar theory, may be made clear, it is necessary to say a few words as to the condition of the subject at the time they were published. For two hundred years mathematical astronomers, many of them of the first rank, had been devoting their energies to furnishing a complete demonstration of the power of the law of gravitation to account for the motions of all the bodies in the solar system within the degree of accuracy of the observations. In the third quarter of the nineteenth century it was evident that this demonstration would soon be made. Leverrier was publishing his tables for the positions of the great planets, while Hansen and Delaunay had completed their work on the moon. For the purposes of navigation, all needed accuracy had been obtained, and from the scientific side there seemed to be but few matters which needed explanation: the final polish which a few industrious workers might give was the last step. There was thus danger that the subject of celestial mechanics might encounter a blank prospect. The number of investigators began to dwindle. At the same time, pure mathematics and physics were showing vast territories to be explored, while the discovery of spectrum analysis and the use of the photographic plate attracted many astronomers who earlier would have devoted themselves to the mathematical side of the subject. From the old point of view this attitude on the part of astronomers

was justifiable. But Hill saw that there were problems other than the mere verification of the law of gravitation by comparisons of theory and observation of the chief bodies in the solar system which would demand solution. He also saw, partly from the industrious work of Newcomb on old and modern observations of the moon, that even the enormous labors of Hansen and Delaunay on the theory of its motion would demand extension and verification if a test of the Newtonian law to the degree of accuracy of the observations were required. For the former object, a new set of problems must be formulated and a start made towards their solution; for the latter, a new method of procedure was practically necessary, for it was almost certain that no one would repeat calculations which appeared to have been pushed as far as was humanly possible with the adopted methods. These two sides of Hill's work are quite distinct, even though they both start from the same memoir.

His own point of view is well expressed in the opening paragraph of his chief memoir, "Researches in the Lunar Theory" (1877): "When we consider how we may best contribute to the advancement of this much-treated subject, we cannot fail to notice that the great majority of writers on it have had before them, as their ultimate aim, the construction of tables; that is, they viewed the problem from the standpoint of practical astronomy rather than of mathematics. It is on this account that we find such a restricted choice of variables to express the position of the moon, and of parameters, in terms of which to express the coefficients of the periodic terms. Again, their object compelling them to go over the whole field, they have neglected to notice many minor points of great interest to the mathematician, simply because the knowledge of them was unnecessary for the formation of tables. But the developments having now been carried extremely far, without completely satisfying all desires, one is led to ask whether such modifications cannot be made in the processes of integration, and such coördinates and parameters adopted, that a much nearer approach may be had to the law of the series, and, at the same time, their convergence augmented."

In the following description of this memoir I have made but

little attempt to keep these two sides separate, and, indeed, no such separation is indicated by Hill. He lays, in fact, more stress on the practical side of obtaining better expressions for the moon's motion than on the theoretical questions which he raises. Moreover, rather than the adoption of the modern point of view initiated mainly by Poincaré, it is more correct for historical purposes to approach its main ideas as far as possible with Hill's point of view.

The older lunar theorists had taken the ellipse as a first approximation—that is, at the start the action of the sun was neglected. Hill proposed a first approximation in which a portion of the sun's action shall be taken into account. If an examination of Delaunay's final expressions for the longitude, latitude, and parallax be made, it is seen that the infinite series proceed along powers of five parameters, and that the rate of convergence along powers of one of these, the ratio of the mean motions of the sun and moon, is far more slow than along powers of the others, owing to the presence of large numerical factors. Hill conceived the idea of neglecting all these other parameters, and then finding the series in powers of this ratio alone with all needed accuracy. He set up the equations of motion, solved them, and gave formulas of recurrence which enabled him to avoid the slow approximation methods which generally advanced the degree of accuracy by only one power of the ratio at each step; in his method it advances by four powers of the ratio. The expressions are worked out both literally and numerically, the latter being taken to fifteen significant figures, a number not very much in excess of what is actually required.

As obtained, the coördinates are referred to axes which move with the mean velocity of the sun round the earth, and in this form the expressions involve the time through its presence in multiples of a single angle. In the transformations which are necessary to convert rectangular coördinates to polars, Hill makes full use of the method of "special values," or, as it is now called, of harmonic analysis and synthesis. He was always very fond of this kind of transformation, using it much in later years and even attempting to systematize its use when many hundreds of terms were present.

It would be unjust in this connection not to mention the indebtedness of Hill to Leonard Euler, probably the greatest of lunar theorists since Newton. Euler, as Hill remarks, had had the idea of starting the theory in the same way with moving rectangular axes and with the same first approximation, and had carried it out to a considerable extent in his theory published in 1772. The debt would have been greater had Hill been aware of another paper of Euler's, published in 1768 in the memoirs of the Berlin Academy and entitled "*Sur la variation de la lune.*" In this publication Euler obtained the first two or three terms of the same series which Hill treated so amply, remarking that he believed that a full investigation from this point of view would leave almost no difficulties to be solved. With the observational accuracy of his time, this was true; for, although he did not treat the motions of the perigee and node, approximation methods could have been applied which would have satisfied the needs of the astronomers of his day.

The further steps outlined by Euler and quoted by Hill consist of the determination, step by step, of the terms arranged in powers of the parameters which had been neglected. Each step is to consist of the complete calculation with all needed accuracy of the function of the time and the ratio of the mean motions which multiplies each combination of powers of the remaining parameters. There are several difficulties in following this process. The chief one, which Hill solved in the memoir on the Perigee of the Moon, is the determination of the first new angle, containing the time, which arises. In later approximations this angle also involves all the parameters, and other methods are needed to find the new portions depending on them. Euler possibly foresaw this; Hill certainly did, but he never carried his work to the degree of approximation which would need them. The method has been used by the writer for the construction of a complete theory of the moon's motion.

The expressions for the coördinates referred to the moving rectangular axes have another property; they form Fourier series, and are therefore periodic. The resulting orbit in this moving plane is consequently closed. Recognizing this fact,

Hill draws the curve. But he saw that the orbit was of interest apart from its application to the lunar problem, for he immediately proceeds to trace, with some care, orbits for values of the ratio of the mean motions other than that which holds for the actual moon and sun. He thus obtains a family of such orbits. It is Hill's idea of the periodic orbit which, developed chiefly by Poincaré and G. H. Darwin, has given new life to the whole subject of celestial mechanics and has induced many mathematicians to investigate on these lines. The treatise of the former, "*Les méthodes nouvelles de la mécanique céleste*," is based mainly on the idea. Darwin actually traced many such orbits under varying conditions. During the last twenty years numerous mathematicians and astronomers have treated different phases of the subject which, according to Poincaré, is the only means of approach to regions of research previously considered impenetrable.

There is still another portion of this memoir which has been largely used as a foundation for investigations into the stability of celestial systems. If the eccentricity of the earth's orbit round the sun be neglected, it is possible to write the relative energy equation in a finite form. Referred to the same moving axes, the square of the velocity can, in fact, be expressed as a finite algebraic function of the coördinates. Since the square of the velocity can never be negative, this function equated to zero gives the equation to a surface which the moon cannot cross. As the surface consists of various ovals and folds, we can obtain certain limitations on the path of the moon, and therefore carry forward the question of the stability of its motion one important step. Hill draws the surfaces for a limited case. Darwin made extensive use of a similar diagram for a more extended case, and many others have followed on the same lines.

Thus this memoir of but fifty quarto pages has become fundamental for the development of celestial mechanics in three different directions. It would be difficult to say as much for any other publication of its length in the whole range of modern mathematics, pure or applied. Poincaré's remark that in it we may perceive the germ of all the progress which has been made in celestial mechanics since its publication is doubt-

less fully justified. It has sometimes been said that Hill did not appreciate at the time the importance of his work. Hill was far too modest about his own achievements to lay any such stress on his productions as has the scientific world. But it does not require an extended study of his memoirs to see that his vision often went beyond the particular matter in hand. A deviation into some problem arising from work on which he was engaged, or a suggestion for future investigation at the end of a paper, is almost characteristic, and the value of these suggestions, shown later, proves that he either saw further or had developed the idea more fully than his remarks would indicate.

The second memoir of 1877, "On the part of the motion of the Lunar Perigee, which is a function of the mean motions of the Sun and Moon," has already been referred to. It is essentially a continuation of that part of the researches which deals directly with the lunar problem, although published earlier. While not so far-reaching from the point of view of future developments, it is even more remarkable as an exhibition of Hill's powers of analysis. In it the determinant, with an infinite number of elements, is raised from a nebulous possibility to an instrument of computation. Hill's periodic orbit contained only two of the four arbitrary constants which the complete solution of his differential equations requires. He therefore proceeds to find an orbit—no longer periodic—differing slightly from the periodic orbit, but still satisfying the differential equations to the first power of the small variation. The equations obtained are two of the second order, and linear with respect to the two unknown dependent variables. An able analysis, with the use of known integrals, enables him to reduce the solution to that of one of the second order in the normal form:

$$\frac{d^2 p}{dt^2} + V p = 0$$

where V is a known Fourier series depending on the time. Knowing the form of the solution:

$$p = \sum a_i \cos \left\{ c (t - t_1) + 2 i (n - n') (t - t_0) \right\},$$

from previous work in the lunar theory which he justifies by general considerations, Hill substitutes and obtains an infinite series of linear equations for the determination of the unknowns a_i . But c is also unknown and it does not enter in a linear form. The a_i are eliminated by means of a determinant with an infinite number of rows and columns equated to zero; this is, therefore, a determinantal equation to find c , the main object of the investigation.

Then follows a remarkable series of operations. The determinant is reduced to a convergent form (though it was left to Poincaré to furnish the proof of convergence) by dividing each row by a suitable factor which reduced every element of the principal diagonal to unity. Next, the unknown c must be isolated; Hill achieves this by recognizing that if c be a root, so must $c + 2i$ be also a root, and that therefore all the roots can be expressed by a cosine function. On the assumption that there are no other roots, he equates the determinant to the cosine function, obtaining the constant by comparing the highest (infinite!) power of c on each side of the equation. A particular value of c (not a root) can also be inserted in the identity thus obtained. In this way Hill reduces the work to the computation of an infinite determinant every element of which is known. He gives a general method for its expansion which enables him to tell at once the order of the terms neglected by cutting off the series at any place. Each term of this series, however, consists of singly, doubly, . . . infinite series which must be summed. The labor at this stage was very great, and it caused a corresponding liability to error. Hill carried it through with complete success in its general form, afterwards substituting numbers and determining c to sixteen significant figures. The principal part of the motion of the moon's perigee is immediately deducible from c . President Woodward relates that the determinant was solved during one of two trips which Hill made to the northwest region of Canada; I imagine, however, that this statement refers to the method adopted rather than to the actual computation.

The story of these two memoirs is incomplete without a notice of the work of J. C. Adams on somewhat similar lines. Almost immediately after their publication a brief paper by

him appeared in the Monthly Notices of the Royal Astronomical Society. After acknowledging the importance of Hill's work, he proceeds to give some account of his own researches. He had also seen the value of Euler's method, and had obtained Hill's periodic orbit to a high degree of accuracy. But he had used polar coördinates, and consequently the rapidly converging series which Hill had deduced with such elegance for rectangular coördinates referred to moving axes were not available. Also, instead of continuing the natural development to obtain the motion of the perigee, he had turned aside to find the principal part of the motion of the node. In so doing, the equation for p (see above) comes naturally into the normal form of the second order. At this point his method of investigation is almost parallel with Hill's. He sets up the infinite linear system, introduces the infinite determinant, expands it, and makes the numerical application to the nodal motion. His results only are given, but further information as to the extent of his actual work can be obtained from the extracts out of his diaries and unpublished manuscripts now printed in the second volume of his collected works. As Dr. Gaisher remarks in his memoir of Adams, the coincidence of the methods of Hill and Adams is very striking. It was the second important occasion that Adams had been forestalled, but here his inveterate habit of postponing publication in order to put a final polish on his work must be blamed. Indeed, much of this particular work on the lunar theory was done by Adams before Hill had left college.

It is convenient at this stage to take up Hill's work rather by subject than in chronological order. The periodic orbit used with such excellent effect in the lunar theory is tried later (1887) on the motion of the satellite Hyperion as disturbed by Titan, and the results applied in a following paper to obtain the mass of the latter. These were written before the publication of Poincaré's researches. Only on one occasion did he make it the subject of a theoretical research, and it was then probably stimulated by reading Poincaré's *Mécanique Céleste*. As the title, "Illustrations of Periodic Solutions in the Problem of Three Bodies," indicates, it consists of applications to certain bodies in the solar system.

From time to time a paper was published extending the applications to the lunar theory. In one, the periodic orbit is made to include the terms which depend on the ratio of the parallaxes of the sun and moon as well as on the ratio of the mean motions. Another contains the terms dependent on the latter ratio and on the first power of the solar eccentricity. In still another paper he calculates the expression for the principal part of the motion of the moon's perigee as far as m^{11} literally, in order to settle the correctness of Delaunay's value, which had been questioned as to certain of the earlier powers of m by Andoyer. Beyond these he seems to have made no effort to continue the work in this direction. Possibly this was due to the heavy labor on the theories of Jupiter and Saturn which engaged him at least until 1892. In fact, as early as 1888 he stated, in a letter to Sir George Darwin, that he scarcely expected to proceed with the subject.

Prof. F. R. Moulton, who has himself done much to develop the ideas of Hill and Poincaré, chiefly in the domain of periodic orbits, has given in *Popular Astronomy* an account of Hill and his work. In referring to the lunar theory, he writes:

"The question naturally arises why Hill did not complete his lunar theory, according to his announced intention and plans as set forth in his first paper on the subject? The question had often arisen in my mind. After one of the meetings of the National Academy in Washington, a few years ago, Hill asked me to take a walk with him. It was one of the splendid afternoons that are often found in Washington in late April. The bright green vegetation and newly opened flowers were particularly beautiful to us, because they were still held back by the cold winds which at that time of the year were sweeping across the Northern States. Hill laid our course down one of the beautiful avenues for which Washington is noted and out toward the country. Soon the invigorating air and the glow from the exercise put us in the best of spirits. I then asked him to give me some account of his work on the lunar theory. With the utmost modesty, yet with considerable freedom, he told me about it.

"At the time Hill was publishing his papers on the lunar theory Simon Newcomb was in charge of the American Ephemeris and Nautical Almanac office in Washington, and he had the worthy ambition to get out new tables of the motions of the planets which would surpass all those in existence. The most troublesome problem in this program was the determination of the mutual perturbations of Jupiter and Saturn. Newcomb recognized Hill's ability, and assigned him the task

of developing the theory of the motion of these planets. The result of this assignment is comprised in the 577 pages of volume III of Hill's Collected Works, and required seven and one-half years of steady computation for its completion. Hill told me that he thought the greatest piece of astronomical calculation ever carried out by one man was Delaunay's lunar theory, and that his work on Jupiter and Saturn came second. Now the greater part of this work was straight computation by methods which were largely due to Hansen, and which could have been carried out under Hill's direction by men who did not have his great ability for original work. It seems probable that science lost much because Newcomb caused Hill to spend about eight years of the prime of life on this work. At any rate, this was the direct cause of his laying aside, as he thought for a time only, his researches on the lunar theory."

His fondness for Delaunay's methods has already been mentioned. One of his most valuable memoirs is an application of them to the calculation of the smaller perturbations of the moon's motion which arise from the action of the planets and the figure of the earth. It had long been accepted that the most efficient way of treating these was through the method of the variation of arbitrary constants. But most of Hill's predecessors had found their action independently of the solar perturbations of the moon—that is, the orbit was considered to be elliptic before the application of these small forces; if the action of the sun were taken into account at all, it was through a troublesome series of approximations. Hill, using Delaunay's methods and results, showed, in a short paper on the Jovian evection, that the whole action of the earth and sun on the moon could be treated as known from the start, and that, therefore, only one approximation was needed in order to get the effect of any disturbance whose square could be neglected. All later investigators have used this method. The formulæ of Delaunay are literal, while Hill's final equations for the calculation of the effect of any small disturbing force have the great advantage of well-determined numerical coefficients to be multiplied by the constants which depend solely on the nature of the given force.

In an earlier paper he had also shown how the disturbing function for direct planetary action can be expressed as a series of products, one factor in each product containing the co-ordinates of the earth and moon only, while the other con-

tained those of the earth and planet only. The former could therefore be computed once for all; it was the latter which required separate computations for each planet. This paper has also formed the basis for all the complete calculations of the planetary disturbing forces which have been made since its publication in 1883.

But Hill's most extensive application of Delaunay's theory is made in its original form to the calculation of the inequalities produced by the figure of the earth. While he carried these to the degree of accuracy needed for observation, the method appears to be somewhat long and complicated. It has to be applied in a literal form, and this requires expansions which converge very slowly. As a matter of fact, a few days' work with his methods adopted for the planetary terms will furnish the inequalities with all needed accuracy. In the first part of this paper Hill, not content with the values for the flattening of the earth which were then in use, deduced one directly from a large number of pendulum observations all over the earth. The result, $1/288$, is considerably larger than most of the other determinations, and notably so than that of Helmer, $1/298$, deduced from the same class of observations. The memoir occupies over a hundred and forty pages, and must have demanded an enormous amount of careful and accurate algebraic computation. To complete the account of his work on the lunar theory, mention must be made of his calculation, by de Pontécoulant's method, of the principal inequalities produced by the motion of the ecliptic. Hansen was the only writer who had found the term in longitude as well as that in latitude, and nearly all his calculations of the small perturbations are doubtful. Hill, of course, obtained correct results as far as he went in the matter.

Newcomb had taken charge of the American Ephemeris in 1877. This gave him the opportunity he had longed for: to construct new theories and tables of the moon and planets, with constants which should be determined by a full use of the great mass of observations which had at that time accumulated. Even Newcomb, with his great energy and power for hard work, saw that this was a task beyond the capacity of one man, and for the most difficult part, the theories of Jupiter and

Saturn, there was but one man on whom he could rely. It needed great ability and knowledge of celestial mechanics, as well as accuracy and care, in working out the numerical details. He induced Hill to undertake the task, and, in order that he might make full use of the computing staff, to settle in Washington. Hill yielded, and for ten years did most of his work there. But he always found it difficult to make use of ordinary computers; he lacked the organizing power which Newcomb possessed in so high a degree and which enabled the latter to turn out such vast quantities of results. Hill did most of the original computations himself and only used computers to a small extent in the verification of his results.

The method adopted is that of Hansen, with only a slight modification, which consisted in expressing the computations directly in terms of the time instead of using two auxiliary angles. That he used an old method in preference to devising a new one is perhaps unfortunate, even though the result leaves little to be desired. Had he taken more time over the preliminary stages we should probably have had something new and original, for Hill was then at the height of his powers as a mathematician. But he was under some pressure from Newcomb, who wished to complete his great plan during his tenancy of the office of director, and Hill himself may have desired to finish the calculations as soon as possible in order that he might return to West Nyack. However this may be, he completed the task successfully, as may be judged from the small residuals which he obtains after a comparison with observations extending over 150 years. The tables which he formed from the theories of the two planets are now used in most of the national ephemerides.

In 1882 Hill published a memoir of some length on Gauss's method for computing the secular perturbations of the planets. Gauss had outlined only the general idea, which amounts to obtaining the mean values of certain functions at about a dozen points of the elliptic orbit of the disturbed planet, equally distributed with respect to the angle which is adopted. Much work has, however, to be done before this can be shaped for actual use. Hill takes it up, and develops in detail the formulæ to be used. In the course of the analysis he finds that a

considerable portion of the calculation depends on three elliptic integrals which may be needed for values of the argument up to 50° . Consequently a large part of the paper consists of the tabulation of these to eight places of decimals at intervals of a tenth of a degree; the first and second differences are also printed, so that the tables are in form ready for interpolation. As an example, he computed the secular perturbations of Mercury by Venus with great accuracy. These long computations are an evidence of Hill's industry and full control of his methods; he had tried them out in detail, and could therefore give them in the most effective form. At the end of the paper is an appendix in which he gives a further improvement on the method as a result of his experience with it. The most complete application of Hill's devices is the computation of the secular perturbations of the four inner planets by Prof. Eric Doolittle. Hill returned to the subject in two memoirs published during the year 1901. He was obviously stimulated by reading the memoirs of Halphen and Bour on the subject, and seeks to extend the work of Halphen as he had previously done that of Gauss.

In these years Hill published a number of short papers in the *Analyst*, a journal no longer in existence. Sometimes they are merely solutions of well-known problems; at other times simplifications of proofs of theorems which had evidently presented difficulties to him, and which he felt needed elucidation or elaboration—two favorite words with him. But Hill was not a great expositor; even for those familiar with the subject his work is often difficult, and sometimes obscure. Newcomb used to say that if Hill had only had the faculty of explaining his own ideas, he (Newcomb) might have avoided many an error and saved much time. Hill's ability to assimilate and extend the work of others, at any rate in his earlier days, doubtless prevented him from appreciating the difficulties of others. When the reader is used to Hill's style of composition and his general plans in writing out what he had to say, his arguments are much more easily grasped, but he is rarely anything else but concise.

In his last years Hill still continued to publish in spite of failing health. He covered a variety of topics, several of them

quite away from the region of celestial mechanics. That these papers have not attracted any very great attention may possibly be because they are on lines in which his name is not well known; time alone can furnish a judgment of their value. One of the most extensive of them is a memoir on dynamic geodesy, the last in the fourth volume of his collected papers, and not previously published elsewhere. In the prefatory remarks to it he says: "The endeavor in this memoir is to elaborate a theory of gravity which dispenses with the idea that we must know the elevation of the place of observation before we can make comparisons." In it he makes a variety of suppositions concerning the differences from an ideal earth for which exact formulæ can be supplied. Some of these are worked out in considerable detail, with occasional reductions to numerical results.

If an attempt is made to regard Hill's work as a whole and to try to find out his point of view, one thing stands out clearly: a desire to obtain exact knowledge about natural phenomena, in however limited a field, which could be expressed in a numerical form. He never seemed to hesitate about making long calculations, and apparently had a positive liking for obtaining his results to many places of decimals. But, unlike the tendencies of those who engage much in computation, his mind did not seem to get cramped by figures. Not only could he see both trees and wood, to adopt a familiar simile, but could trace paths in the wood and keep his eyes open for those roads which led in directions other than that he was exploring. He had remarkable ability for algebraic manipulation, which reached its highest manifestation in the memoir on the perigee of the moon. The more modern sides of mathematics appealed to him but little; if a formula or a series could be reduced to numbers, such questions as convergence did not trouble him much—a point of view which has later been fully justified by Poincaré. He seemed to take but little color from the work of others. Even when, as in many cases, he starts with the results of some previous investigator, his writing shows but little influence of the source of his ideas; it is individual, and carries the reflection and methods of his own mind. Above all, however much in detail he works out his themes, his memoirs carry that in-

definable quality of the master which tempts the reader to explore further.

In the introduction to the four volumes of Hill's collected works, published by the Carnegie Institution of Washington, M. Poincaré has given an appreciation of their value. I quote the first and last paragraphs:

"M. Hill est une des physionomies les plus originales du monde scientifique américain. Tout entier à ses travaux et à ses calculs, il reste étranger à la vie fiévreuse qui s'agite autour de lui, il recherche l'isolement, hier dans son bureau du Nautical Almanac aujourd'hui dans sa ferme tranquille de la vallée de l'Hudson. Cette réserve, j'allais dire cette sauvagerie, a été une circonstance heureuse pour la science, puis qu'elle lui a permis de mener jusqu'au bout ses ingénieuses et patientes recherches, sans en être distrait par les incessants accidents du monde extérieur. Mais elle a empêché que sa réputation se répandit rapidement au dehors; des années se sont écoulées avant qu'il eût, dans l'opinion du public savant, la place à laquelle il avait droit. Sa modestie ne s'en chagrinerait pas trop et il ne demandait qu'une chose, le moyen de travailler en paix." . . .

"Ainsi aucune des parties de la Mécanique Céleste ne lui a été étrangère, mais son œuvre propre, celle qui fera son nom immortel, c'est sa théorie de Lune; c'est là qu'il a été non seulement un artiste habile, un chercheur curieux, mais un inventeur original et profond. Je ne veux pas dire que ces méthodes qu'il a créées ne sont applicables qu'à la Lune; je suis bien persuadé du contraire, je crois que ceux qui s'occupent des petites planètes seront étonnés des facilités qu'ils rencontreront le jour où en ayant pénétré l'esprit ils les appliqueront à ce nouvel objet. Mais jusqu'ici c'est pour la Lune qu'elles ont fait leurs preuves; quand elles s'étendront à un domaine plus vaste, on ne devra pas oublier que c'est à M. Hill que nous devons un instrument si précieux."

The impressions of those who knew Hill personally give an idea of the man which is an attractive complement to the account of his scientific life. In the course of a brief account of him in the *Astronomical Journal*, President R. S. Woodward writes:

"Unfortunately for most of his contemporaries, but perhaps fortunately for him, Hill was too little known, and hence too little appreciated, especially by his fellow countrymen. He was so absorbingly preoccupied with his researches that he had scant leisure for association even with his more intimate friends. He held himself mostly apart from the ordinary affairs and amenities of society, and consecrated his energies to the less obvious realm of celestial mechanics. But this was not because he lacked the social instincts common to mankind. To

those who knew him well he presented a singularly attractive personality. Although his innate modesty obscured his superior talents in a large or in a mixed company, he was a delightful companion for a long walk and a very stimulating host to, or guest of, his chosen friends individually. His transparent sincerity, his steadfast but unostentatious devotion to elevated ideals, and the effective simplicity of his life will be long remembered as among the finer qualities of the man Hill by those who had the good fortune to come into closer association with him."

An interesting picture has been contributed by Mr. A. S. Flint, of the Washburn Observatory. In a letter to the writer he says:

"I first met Dr. Hill early in my period of residence at Washington, 1881-1889. He was a regular attendant at the meetings of the then sole scientific society in Washington, the Philosophical Society. Any stranger would have supposed that Hill was some very ordinary farmer that had strayed into the meeting. Professor Ferrel was a good deal of a companion piece to him, and I think the two usually sat together at those meetings. No history of scientific Washington would be complete without a portrait of Dr. Hill, always dressed the same and always proceeding in a walk of short, quick steps, with his umbrella, hanging from one hand, held out forward, except when it was raised against rain or hot sun.

"I remember calling on him once in his large room in a rather economical quarter near Judiciary Square. He was very kindly. I was then enjoying my first experience in riding a bicycle, and I remarked to Mr. Hill that he ought to have one for traversing Washington's 'magnificent distances.' He replied quickly, with a farmer's abrupt tone, 'It would be a great extravagance!' But he had understood me to mean he should have a riding horse, and apologized gently when he understood that I had said 'a bicycle.'"

I am much indebted to Dr. Henry B. Hedrick for the following account of his association with Hill, which he has written at my request:

"My first recollection of George William Hill dates back to the early eighties, when I remember seeing him start out from a house on P street, in Georgetown, D. C., opposite our school, on his Sunday walks, with two companions, William L. Shoemaker, a poet, and Eben J. Loomis, a colleague in the Nautical Almanac office.

"A few years later, about 1890, I became the fortunate one to accompany Hill. At that time I lived at Glencarlyn, Virginia.

"Mr. Hill would walk from his room near the City Hall, in Washington, D. C., to my house, a distance of about eight miles, and then to

gether we would explore the woods and streams for miles beyond my place, taking a light lunch with us, and returning to Glencarlyn. After dinner he would never permit me to hitch up the horse, but insisted on walking back to Washington. One serious objection to driving back was that he would miss the pretty path along Lover's Run. In this way he would walk 25 or 30 miles a Sunday, with little apparent exertion.

"He was a most agreeable companion. He knew the infrequent haunts of the fragrant arbutus and the wooded hillsides completely covered with laurel blooms. The whole country for twenty miles round Washington was an open book to him. I could never take him anywhere in Virginia that he had not been often before, and he was fully as familiar with the country in Maryland north of Washington. He knew all the trees and flowers, and in most cases their common and botanical names, genera, and species. He was as well informed on the botany of these regions as those who made such their special study. In Ward's 'Flora of Washington and Vicinity' it was at first stated that no hemlocks grow near Washington. Mr. Hill called the author's attention to a grove of hemlocks, far from any road, at the mouth of Scott's Run, where it makes its final fall into the Potomac, about 10 miles above Washington.

"Mr. Hill made two trips into the wilds of Canada and several walking trips through the mountains of Virginia, West Virginia, and North Carolina. Everywhere he went he used his marvelous powers of observation, and could talk about the flora he found on these longer trips with the same full knowledge he displayed about those round Washington or round his own home in the valley of Hackensack.

"The birds we saw interested him as well as the flowers. On my visit to his home in the spring of 1908 I found him in front of his house watching some birds in a tree. He said then he was unable to take any more long walks, but that he computed a little each day.

"He took some walks in Germany also, but told me it was not interesting to walk where people spoke a different language.

"Among his books were a great many on travels, especially of drives and walks. I remember one that interested him particularly, and which he lent me, was about a driving trip through West Virginia.

"He did not, I believe, have any botanical collection, leaving these matters to others, as he did physical observations in astronomy. In fact, in these walks of his, which were such a characteristic part of his life and perhaps his main pleasure outside of his work, he displayed the same striking qualities of mind as were manifest in mathematical fields. The roads and paths made by others he used whenever they took him in the direction he wished to go, but at the earliest moment possible he left the beaten roads and struck out into the pathless wood, ever searching for and finding the hidden, the unusual, and the beautiful.

"When I entered the Almanac office, in November, 1886, I was given a desk in Mr. Hill's room. At first there were two other assistants in our room, but later Mr. Hill and I had a room to ourselves, and continued so until he left the office, in June, 1892.

"In those days an able assistant was assigned a piece of work and left to choose his own method of accomplishing the desired result. Thus Mr. Hill was assigned the task of preparing the theory and tables of the motion of Jupiter and Saturn—a difficult problem, in which, however, Mr. Hill was greatly interested. He never had, while I was in the office, any routine computing, nor routine duties incident to his position. He was at all times the master of his work. It might appear that the greater part of the work was straight computation, which could have been carried out under his direction by men who did not have his ability for original thought: that is one of the consequences of efficient planning—the work looks so simple when it is finished.

"The best method to pursue requires a great deal of thought and originality, and often this knowledge can be obtained best by actually doing the work. Mr. Hill always had all the assistance he thought he could use to advantage. He told me once that he did not like having an assistant even to duplicate his work, as it would be impossible for the two to keep together, and it would necessitate his carrying in mind the formulæ not only of the part on which he himself was engaged, but also of the part his assistant was doing. He considered that he conserved time and energy by completely finishing up one part of the calculation, even though he did a major part himself. Then he was free to turn his whole attention to the next part. He was an astonishingly rapid and accurate worker. Several times I noticed that his calculations in a single day would cover two large sheets of computing paper, 16" x 21".

"Mr. Hill was most punctual about arriving at the office, but often worked after office hours in order to reach a desirable stopping place. At that time it was customary, instead of singling out delinquent ones for reprimand, to issue a general order to all the assistants covering the point in mind. To stop tardiness on the part of a few, an order was issued calling attention to the fact that office hours were from 9 to 4. Mr. Hill initialed the order as required, and never thereafter remained after 4.

"He received very few visitors during office hours. Among these callers were Dr. Robert S. Woodward and Prof. Asaph Hall, Sr., two of Mr. Hill's most intimate friends. When Mr. Hill first came to Washington he stayed with Professor Hall several years—that is, until Mrs. Hall's long illness, in the fall of 1881. After that he took rooms on Indiana avenue near the City Hall, where he remained the balance of the time he was in Washington. It was Mrs. Hall who entered Mr. Hill's name as a candidate for Professor of Mathematics in the Navy, the corps to which Professor Hall belonged. At the time there were two vacancies, and Mr. Hill passed a most brilliant examination, away

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ahead of all competitors, but for political reasons did not receive the appointment. Mr. Hill told me years afterwards that it was a very hard three-day examination, and that he thought the ordeal injured his health.

"Soon after the completion of his theory of Jupiter and Saturn—that is, in June, 1892—he resigned from the Nautical Almanac Office, where he had spent over thirty years, as he could finish the preparation of the tables of Jupiter and Saturn better at his home. When he was a small boy his parents moved from New York City and settled in the small village of West Nyack, N. Y., then called Nyack Turnpike. Both his father and grandfather were artists, and they were attracted to this place by the picturesqueness of the Hackensack meadows. After the death of his father, in 1879, he obtained a house his father had bought. Here he had his library and his desk. Here he worked and slept, taking his meals with his sister, at the family homestead, a few rods away.

"The house contained five rooms on the first floor, with a small attic, and stood near the road, in an acre lot, nearly surrounded by other houses. Although he always went wherever his work called him, it turned out that this place was exceptionally suitable. He lived here while he gave his lectures on Celestial Mechanics at Columbia University and while he was president of the American Mathematical Society. It is but 24 miles from New York City, on the West Shore Railroad, and thus as convenient to that city as could be desired. The roads in the neighborhood are kept in excellent condition and the country is well and thickly settled. He had many neighbors, but his house was sufficiently distant from the others so that he could work at his desk quietly, as all should be who work mentally.

"On entering his home at West Nyack one could not help being impressed by his library. There were bookcases in all his rooms, and they were all full. There were literally books everywhere. He received gratuitously the publications of observatories and mathematical and astronomical societies, and the purchase of every book he wanted was one item of expense in which he never restricted himself. For many years he had an order in Europe for a book he wanted that was out of print. When he obtained it he had to pay a good round price, but that was all right, as he said he could not get it for less. No price was too great for a good book. Before he died he gave some of his books to Rutgers College, and the balance he left in his will to Columbia University.

"He never appeared to be melancholy or morose. To him the world was always bright. He could tell amusing stories of some hardships on his excursions, but not a word of complaint. He mingled with his fellow-men wherever he went, and was always glad to see his friends, both abroad and at his home. He freely helped all who asked his aid.

"In the spring of 1908, when he attended the National Academy meeting, he presented to me a copy of a paper which he had just read

before the American Mathematical Society, entitled Subjective Geometry, remarking, as he presented it, that he expected it to make a stir, and that the non-euclidian geometers would answer it.

"I remember how his face would fairly beam on the days the National Academy was in session, as he started off to attend the meetings of the council. He was always present at the meetings of the Academy as long as he was able to attend. I could always look forward to seeing Hill in the spring, when the Academy came to Washington. At these meetings he was retiring and modest, but not timid, as some one has said. It always appeared to me as though it were the other members who were the timid ones. Few spoke to him, but those who did get up courage so to do found him most agreeable and not in the least hard to approach, and a good conversationalist on almost any subject.

"Still, however much he enjoyed these gatherings, he did not let them interfere with his main purpose of life. Like his walks, they may be called his recreation, using that term in its best sense. These were not the incentives for his achievements, and so his life and work continued, after he became eminent and distinguished, in the same way as before.

"In order to accomplish his life work he early trained himself to avoid luxuries. A glass of wine a year with his friends would do no harm, but no feasts, which so often follow in the wake of renown, should turn him from his path of service. He never talked on religion or temperance, but rather preached by his example. His life was an inspiration to all who knew him.

"He was not the head of the Nautical Almanac Office, but he may well be called its spirit. All parts of it—the stars, moon, and planets—show the effects of his mind. He gave new methods to workers in celestial mechanics and extended the boundaries of mathematics. He never received pay for any of his epoch-making ideas; never retired or ceased his labor; never sought nor received a pension. All was given gratuitously for the benefit of his fellow-men. He was the ideal altruistic man of science."

Referring to Hill's connection with Columbia University, Professor Jacoby writes in the *Columbia University Quarterly*:

"It was in 1898 that Rees obtained from the late Catherine Wolfe a sum sufficient to engage Hill for several years, and he was appointed Lecturer in Celestial Mechanics. That such lectures would attract few students, or none, Rees had predicted to the writer. Hill, who had a high sense of honor, soon offered his resignation on the ground that he had no audience and was not earning his compensation. But Rees was ready with a plausible refusal, and insisted that Hill would amply satisfy the duties of the post if he would but write his lectures so that they might be printed for the benefit of future astronomers. Hill did so; but after the lapse of a couple of years he insisted on returning to Columbia the entire sum that had been paid him, this time on the ground that he did

not want the money, and that the care of it was an annoyance to him. Rees accepted it as a gift to the department of astronomy and it was used for purposes of research."

Hill received numerous marks of recognition in this country and abroad. He was foreign member, or associate, of the Royal Society of London, the Paris Academy, the Belgian Academy, and several societies which are less national in their scope. He was awarded the Gold Medal of the Royal Astronomical Society in 1887. Later he received the Schubert prize from the Petrograd Academy, the Damoiseau prize from the Paris Academy, and the scientific blue ribbon of the British Empire, namely, the Copley Medal, from the Royal Society in 1909. Columbia, Princeton, and Rutgers conferred on him their honorary LL. D., and Cambridge University, England, its honorary Sc. D. The list is perhaps not so imposing as that of many a man whose reputation will endure for less time than Hill's, but some of these foreign decorations are achieved by few scientific men. Hill himself was so little known personally, even in his own country, that all such awards were based on his published work. He rarely attended congresses or scientific meetings, and so did not get an opportunity to explain in language which the majority of scientific men could understand the ideas which lay at the base of his chief memoirs. Almost the only occasions when Hill emerged from his retreat at West Nyack were from 1894-1896, when he was president of the American Mathematical Society, then in its early years, and in 1898 to 1901, when he was lecturer at Columbia on celestial mechanics. While living in Washington, however, he would attend the meetings of the Academy of Sciences, and in later years, when his health permitted, he usually made an effort to be present at the annual spring meeting of the National Academy.

Among the unpublished manuscripts left behind by Hill, and now deposited in the library of Columbia University, are two of some interest. The earlier is a carefully written diary, illustrated with photographs, containing an account of the second expedition which he made to the northwest of Canada. The route followed took him, with a companion and guides, by rivers and lakes from Lake Superior to Hudsons Bay and

back. It must have been sufficiently laborious, with the numerous portages of the canoes and supplies, but Hill apparently found enough spare energy to record everything of sufficient interest to appeal to him.

The other manuscript must have cost him great labor. It consists of the lectures which he delivered as lecturer on celestial mechanics in Columbia University from 1898 to 1901. He evidently intended them to be a more or less complete account of the methods by which the motions of the moon and planets are computed. There are long algebraic developments which achieve the end he had in view, but the absence of explanations, except in a very concise form, would make them difficult for one not familiar with the subject.

Hill never married. In his last years he suffered from poor health, and rarely left his home; so that his death, on April 16, 1914, from heart failure, scarcely came as a surprise to those who knew him.

A great scientific figure has passed away of a type which is increasingly rare in these times of high organization in every line of educational and scientific activity. With calls on all sides for advice, assistance, lectures, committees, instruction, what chance is there to hope that we may produce scholars most of whose thoughts and time may be devoted to the increase of knowledge concerning the inner mysteries of science? Is it not to be feared that by our very efficiency in coördinating all means to this end we shall extinguish the spark which appears in but a few individuals of any one generation? Hill yielded but once to such a call, and although the result was an edifice to which any one might look back with pride, the world will be poorer because of its construction, if it prevented great discoveries in unknown regions. Whether this be so, we may not know; but we can at least hope that in the one great nation which is and may be free, if it will, from the great overturn of the ideals of our modern civilization, there may still arise a few who, possessing great powers, will also show the single-hearted devotion to science which is so amply exemplified in the life of George William Hill.

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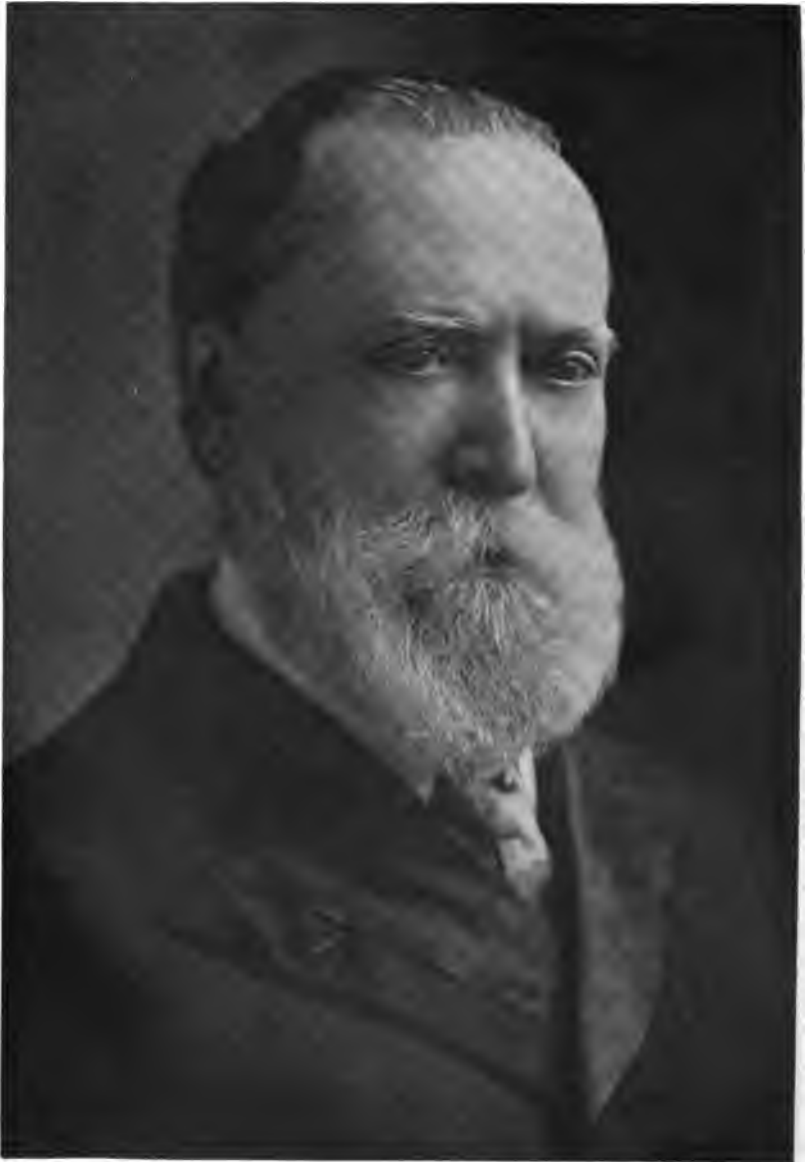
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Geo. N. Bull

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THEODORE NICHOLAS GILL

1837-1914

BY

WILLIAM HEALEY DALL

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THEODORE NICHOLAS GILL.

BY WILLIAM HEALEY DALL.

The subject of this memoir was born on Broadway, New York City, below the City Hall, March 21, 1837, and died at Washington, D. C., September 25, 1914. He was the son of James Darrell and Elizabeth Vosburgh Gill. The father was the son of a merchant of St. Johns, Newfoundland, descended from an old Devonshire family. The mother came of old New York Dutch stock.

A few years later the family moved to 164 Grand street, on the border of the city, which was then almost the country, with open fields, trees, and groves in plain view. The city of New York had at that time only some 300,000 population.

The boy received the rudiments of education from his mother, and at the age of eight was sent to the Mechanics' Grammar School on Crosby street, then a highly esteemed educational establishment.

A year later his mother died, the father gave up housekeeping, and his son was placed in charge of a private tutor at Greenville, N. Y. Here he received a very thorough training in Latin and Greek, the father having ambitions that the son should eventually become a clergyman.

Later his father married again and resumed housekeeping on West 26th street near Sixth avenue, and still later moved to Brooklyn. Young Gill was then recalled from Greenville and sent to a private classical school in the city. •

His love of nature and instinct for collecting developed early, and it is perhaps not merely a coincidence that, in coming by the ferry from Brooklyn and daily passing the great Fulton fish-market, his attention should have been especially drawn to the study of the fishes of New York.

As young Gill arrived at the age when it seemed necessary to decide on a profession, it became evident to him that he had no taste for theological studies. After due deliberation he decided to study law and entered the office of S. W. and R. A.

Gaines, a well-known law firm of that period. The latter partner had married a sister of James Darrell Gill, and was therefore a connection interested in Theodore's success in life.

His extraordinary gift of memory doubtless enabled him to absorb the essentials of legal learning, but an overpowering tendency toward the study of nature greatly abridged his law studies and he never applied for admission to the bar. His visits to the fish-market became more constant, while the adjacent water front sheltered sailing vessels from all quarters of the world, where sailors with shells and curios were daily to be encountered. His grandfather's family being residents of Newfoundland, where the fisheries were of the first importance, he kept himself informed through everything he could reach of matters relating to the subject.

The pursuit of scientific studies at that period, and for a long time afterward, offered no prospect of a self-supporting career. Though there are no data on record, it is reasonably certain that Gill's family must have looked with doubt, if not absolute disapproval, on his devotion to studies which did not promise even a bare living. At all events, with a young family from his second marriage to bring up and educate, Gill's father was not in a position to support him in an unproductive profession.

He was therefore soon left dependent on his own resources, which for years were barely sufficient to maintain his existence.

According to Doctor Gill himself, we find him about this time seeking and obtaining from the Wagner Free Institute of Science in Philadelphia a scholarship which yielded him the meager means of pursuing his studies in natural history, and thus coming in contact with a group of men who helped to lay the foundations of American science. This grant, he stated to a friend some time before his death, was the deciding factor in his resolve to devote himself to scientific studies.

He became acquainted with most of those who at that time in New York were interested in natural history, especially J. Carson Brevoort, whose zoological library was then reputed to be the best in the United States, and D. Jackson Stewart, a wealthy amateur, whose great collection of shells has finally found a resting place in the American Museum of Natural History.

About this time Dr. William Stimpson, the distinguished student of invertebrate zoölogy, while in New York heard amusing references to a young student of law who kept a horse's skull under his desk at the office where he was studying. Investigating this phenomenon further, he made Gill's acquaintance. Partly as a result of Stimpson's report to Professor Baird of the Smithsonian Institution, the latter, always interested in young students of Nature, entered into correspondence with Gill and promoted his studies. A report on the fishes of New York which Gill had in preparation was accepted for publication in the Annual Report of the Smithsonian Institution when its author was only nineteen years old.

Mr. D. Jackson Stewart, in the interest of his collection, financed an expedition to the West Indies, and in December, 1857, Gill made his first visit to Washington and to the Smithsonian better to prepare himself for the undertaking. Here he made the personal acquaintance of Professor Henry, Baird, and others whom he had known previously only by correspondence.

Gill sailed in January, 1858, on a large schooner, with a pleasant group of passengers.

He visited several of the Antilles, and especially Barbados and Trinidad, where he spent some weeks, being cordially assisted by many of the residents. Finding the marine fishes much the same at all the islands visited, he confined his attention especially to the peculiar fresh-water fishes of Trinidad, with very satisfactory results.

After his return he devoted himself to working up this collection. He went to Washington in August, 1858, for this purpose, and stayed for several months with Stimpson, who was occupying a small cottage near the Church of the Epiphany. He also spent much time in Philadelphia, and his report, with several subsequent papers, was published in the *Annals of the New York Lyceum of Natural History*, the predecessor of the present *New York Academy of Sciences*.

In 1859 the death of his grandfather in Newfoundland made necessary a visit to that country, in connection with the settlement of the estate. Gill improved the opportunity by studying the fauna of that remote region.

On his return, through Professor Baird's intervention, he obtained an appointment with a group of workers to whom was assigned the task of reporting on the collections made during the Northwest Boundary Survey under Archibald Campbell. Among these were George Gibbs, the ethnologist; Prof. William Turner, Dr. Stimpson, and Dr. George Suckley. Dr. Caleb Kennerly, the zoölogist of the expedition, had died at sea on his way home from the Pacific coast.

During this period Gill lived at the Rugby House (now the Hamilton House), where he did a large part of his work. Unfortunately, owing to the breaking out of the Civil War, the reports on the work of the Commission were left mostly unpublished, Gill's among them, though some of his preliminary data appeared in the Proceedings of the Academy of Natural Sciences at Philadelphia.

Among those who were working at the Smithsonian in 1861 were F. B. Meek; the paleontologist; Thomas Egleston, afterward professor of mineralogy in Columbia University; Dr. F. V. Hayden, the geologist; Robert Kennicott, the explorer; Professor Matile, one of Agassiz's Swiss coadjutors in physics and at that time an assistant of Professor Henry; Dr. William Stimpson, who was working on the Invertebrata of the North Pacific Exploring Expedition under Ringgold and Rodgers, and August Schönborn, artist, who made most exquisite silver-point drawings of Stimpson's North Pacific crustaceans.

These formed an informal association known as the Megatherium Club, whose members took meals together and foregathered with Stimpson and Kennicott for joyous evenings. The constant fluctuation in attendance, due to the coming and going between Washington and the fields of exploration in the West, tended toward disintegration, and the club virtually dissolved in a few years.

At the invitation of Professor Henry, Gill came to the Institution in 1861, and during the following winter was appointed to the charge of its great scientific library, which had been collected and organized by that eminently capable librarian, Prof. C. C. Jewett. This post he held until 1866, when, at the instance of Professor Henry, the Smithsonian books were deposited as a special collection in the Library of Con-

gress. Gill went with the books to the Capitol as Assistant Librarian of Congress and finally became senior Assistant, retaining that post until 1874. All this time he had retained his quarters in the Smithsonian building, to which he hastened as soon as the usual office hours in the Library were over. There most of his scientific work was done in the midst of an accumulation of books, pamphlets, unfinished manuscript, and débris of various kinds, piled on shelves, desk, and floor in a manner to strike terror to any housewife. However, old James Gantt, the colored dignitary who "looked after the young gentlemen" and prided himself on having been body servant to a former President of the United States, was very willing to obey the injunction that nothing should be touched, and the accumulations continued for many years.

Finally, when the biological collections were transferred with their curators to the new National Museum building in 1909, and the room occupied by Gill formed one of those assigned to the staff of the Bureau of Ethnology, the Professor was obliged to move to other quarters. He regarded the ancient heaps with dismay and relieved himself of responsibility by presenting them, with all their contents, to the library of the Smithsonian Institution.

As will be noticed by the evidence of the bibliography appended to this paper, the earlier publications of Gill appeared in the *Annals of the New York Lyceum of Natural History*, of which he became a member in 1858.

In November, 1860, he was elected a correspondent of the Academy of Natural Sciences of Philadelphia, and for several years his papers, appearing in rapid succession, form a large part of the Academy's volumes of *Proceedings*. With the establishment of the *American Journal of Conchology* in 1865 and of the *American Naturalist* two years later, an opportunity was utilized for printing various communications on mollusks and miscellaneous subjects. After the starting by Prof. S. F. Baird, in 1878, of the series known as the *Proceedings of the U. S. National Museum*, most of Gill's papers were printed there, in the *Smithsonian Miscellaneous Collections*, or in the *Annual Report of the Institution*.

When the United States Fish Commission began its work

under the direction of Professor Baird, he gathered about him a number of specialists who worked up the collections, and to Professor Gill naturally fell a large part of the taxonomic work on the fishes. Hence the annual reports of the Commissioner contain numerous contributions from his pen. He was also associated with Professor Baird in the preparation of the latter's "Annual Record of Science and Industry," published by the Harpers, and its subsequent equivalent which for some years appeared in the annual reports of the Smithsonian Institution, beginning after the appointment of Professor Baird as Secretary, in 1878.

Most of the zoological data of Johnson's *Cyclopedia* and the zoological definitions of the Century and Standard dictionaries were furnished by Gill, though Dr. Elliott Coues acted as supervising editor.

In 1898 Gill acquired a small ornithological magazine called the *Osprey* and for a time associated Coues with him as editor, but the arrangement did not work well and Coues was obliged to withdraw. In 1899 Gill took entire control and with a brilliant coterie of assistant editors carried the periodical on for several years, during which he frequently contributed to its columns.

His contributions to the labors of the Committee on Nomenclature of the American Ornithological Union were cordially acknowledged by them, and his influence in standardizing zoological nomenclature in general has been very great, though in the main indirectly exercised.

Any classification of a large group of animals becomes obsolete with the increase of authentic data and the general progress of science; but that grasp of the subject which includes the best ideas of the current period, and is joined with the capacity to weld them into a well-balanced scheme of classification, is rare. It was possessed by Doctor Gill in an eminent degree. In fact, we shall hardly exceed the bounds of certitude if we call Doctor Gill the most eminent American taxonomist.

His papers were rarely long. He seemed to prefer to take up small groups, such as families and genera, and work out their relations. No great monograph exists among his publications. Their total mass, however, is very great, and their

influence, especially on the classification of fishes, has been profound.

His revisions naturally met with criticism from those long familiar with the existing order. In a majority of cases he lived to see his views accepted by authorities on fishes. His ideas on Avian classification are quite different from those generally accepted, especially in regard to the relative taxonomic value of characters, but it is by no means certain that the views of future ornithologists will not much more closely approximate to those of Gill.

His work on Mollusca, excepting the general classification embodied in the "Arrangement of the Families of Mollusks," was chiefly of the nature of revisions of particular families or genera. The "Arrangement of Families" brought together the most complete knowledge existing at the time of the relations of the different groups of mollusks; but the subsequent advance of science in that respect has been relatively much greater than in mammals or fishes, and Gill's arrangement has at present chiefly an historical value.

Of the Arrangement of the Families of Fishes and Mammals others can speak with an authority denied to the present writer, but the impression left after conversation with experts is confirmatory of their exceptional value.

The present Commissioner of Fisheries has had the kindness to furnish for this memoir the following estimate of Doctor Gill's work on fishes:

"Doctor Gill's chief contributions to ichthyology were his taxonomic papers. In his taxonomy, which was largely supported by his osteological research, he had no equal among his contemporaries in America or abroad. His papers represent a very large amount of painstaking investigation of a character for which he was especially well fitted and for which few active workers have the time, the fitness, or the inclination. His conclusions have been very generally accepted and form the basis for our present classification of fishes. While for years European ichthyologists disagreed with his views, his system has finally been accepted by practically all the active men at the present time. Next to his taxonomic contributions rank his papers on the structure and habits of fishes. His papers on the life histories of fishes also are noteworthy, their chief value being in the assembling and weighing of scattered observations and their presentation in a form that is exceedingly helpful to all workers in this field.

"His knowledge of the biological literature of all countries and all times was amazing and profound. In estimating his influence on science, full cognizance should be given to the readiness with which he placed this knowledge, together with his time and talents, at the disposal of every one, and to the permanent value of the encouragement he was ever most anxious to give to all those who were fortunate enough to be brought in contact with him."

In noticing the death of Professor Gill in the Annual Report of the National Museum for the year ending June 30, 1915, Dr. Richard Rathbun, Director of the Museum, thus expresses himself in regard to his colleague and collaborator:

"Rarely does one find, as in the present instance, the more or less accidental early phases in the groping for a career converge in such a manner as to at once become useful and necessary. Doctor Gill's early training was a most fortunate one, for the splendid classical schooling of his youth gave him a complete familiarity with Greek and Latin, and his legal knowledge, combined with the former, rendered him a judge where questions of nomenclature were involved. His subsequent library training brought him in contact with the world's literature, and this, yoked with great industry and a phenomenal memory, made him the acknowledged master in his chosen field. It also produced a breadth of knowledge that rendered him a fountain of information, and, as some one has stated, 'With the simplicity of the truly great and the truly able he gave freely of his stores of knowledge, so that to all the investigators who came in contact with him he proved an ever-ready source of exact and reliable information and a sound adviser.' It is certain there are few workers in systematic biology in Washington and many other places who have not received assistance from Doctor Gill."

Very soon after his arrival in Washington, Gill became associated with Columbian College, afterward Columbian University, and still later reincorporated under the name of George Washington University. In 1860 he was made adjunct professor of physics and natural history; from 1864 to 1866, and 1873 to 1884, lecturer on natural history; from 1884 to 1910, professor of zoölogy, and for the remainder of his life professor emeritus. The university, in appreciation of his merits, conferred upon him in 1865 the degree of master of arts; in 1866 an honorary doctorate of medicine; in 1870 the doctorate of philosophy, and in 1895 that of laws.

Doctor Gill was naturally elected to membership of many scientific societies, both at home and abroad. He became a member of the American Association for the Advancement of

Science in 1868, and a Fellow in 1874. In 1896 he was elected vice-president of Section F, Zoölogy, and upon the death of Prof. E. D. Cope, the president elect, he succeeded to the presidency of the Association at the meeting held in 1897 at Detroit.

He was elected a member of the National Academy of Sciences in 1873, and represented the Academy at the Boston meeting of the International Zoölogical Congress in 1898, and at the celebration of the 450th anniversary of the foundation of the University of Glasgow, Scotland, in 1901. He was a member of the American Philosophical Society; of the Philosophical Society of Washington; the Biological Society; a founder of the Cosmos Club of that city; a foreign member of the Zoölogical Society of London, and of some seventy other societies and scientific bodies.

As a young man, Gill was slender and rather delicate in appearance, with black hair, dark eyes, and a somewhat brunette complexion. His relatives by his father's second marriage seem to have partaken of a constitutional delicacy, as death removed many of them at a comparatively early age. I have referred to the fact that in his early manhood Gill was compelled to extreme frugality by an insufficient income. It was only in middle age that by inheritance and some fortunate investments he reached what are generally termed "easy circumstances." The hardships of these early years left their impression on his habits, to some of which he clung with amusing pertinacity long after they seemed to his friends and relatives uncalled for. He was fond of social intercourse with intelligent people and seemed to enjoy ladies' society, but never married.

After his youthful expedition to the West Indies he traveled little, and his only visit abroad was to the anniversary celebration of the foundation of Glasgow University in 1901. He found his recreation chiefly in books, conversation with kindred spirits, and at the meetings of the Literary Society.

An occurrence which gave great pleasure both to him and his friends was a subscription banquet tendered him at the Cosmos Club, December 13, 1912, on the completion of the seventy-fifth year of his age and the fifty-sixth year of publication of his contributions to knowledge.

On this occasion his many friends improved the opportunity of expressing their estimation of his merits as a man and a scholar and their gratitude for his many kindnesses in granting to any inquirer the benefit of his encyclopedic knowledge and phenomenal memory.

A paralytic stroke three or four years before his death permanently enfeebled him, and his remaining days were quiet and uneventful.

In September, 1914, he visited his brother, Herbert A. Gill, in the lovely suburbs of Washington, and a few days later was confined to his bed. On the morning of the 25th he was apparently mentally clear as usual and inquired about the news, but before noon he passed away suddenly. The interment took place at Oak Hill Cemetery.

I have to acknowledge my indebtedness to Dr. H. M. Smith, Mr. Herbert A. Gill, Dr. Marcus Benjamin, Dr. Richard Rathbun, Prof. C. H. Eigenmann, and Dr. T. S. Palmer for data furnished by them, either in print or otherwise, and of which I have freely availed myself in the preparation of this memoir. The following bibliography is not intended to be exhaustive, but contains practically all of Doctor Gill's most important contributions to systematic zoölogy and ecology.

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Edward S. Holden

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EDWARD SINGLETON HOLDEN

1846-1914

BY

W. W. CAMPBELL

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EDWARD SINGLETON HOLDEN

BY W. W. CAMPBELL

EDWARD SINGLETON HOLDEN, son of Edward and Sarah (Singleton) Holden, was born in St. Louis, Missouri, on November 5, 1846. His secondary education was received in private schools at Cambridge, Massachusetts, and during the years 1860-'62 in the Academy of Washington University, St. Louis. He was a student in Washington University during the years 1862-'66, receiving the degree of bachelor of science in the latter year. William Chauvenet, author of the well-known *Manual of Spherical and Practical Astronomy*, was professor of mathematics and astronomy in Washington University, and it is probable that Mr. Holden pursued astronomical studies more or less extensive with Professor Chauvenet. Professor Holden's later associates, who are now residing on Mount Hamilton, recall his frequent remark that his interest in astronomical subjects had been aroused on the occasions of visits to Harvard College Observatory while his cousin (by marriage), George P. Bond, was an observer and later (1859-'65) director of that institution. Mr. Holden was a member of Professor Chauvenet's household during a part of his student days, and married Chauvenet's daughter Mary in the year 1871.

Mr. Holden was a cadet in the U. S. Military Academy at West Point during the years 1866-'70. He was graduated in the latter year, with third rank in his class. During the academic year 1870-'71 he was second lieutenant in the Fourth U. S. Artillery. In 1871-'72 he was second lieutenant in the U. S. Corps of Engineers, serving as instructor in natural philosophy in the Military Academy. In 1872-'73 he was instructor in practical military engineering in the Academy. He published an octavo treatise on "The Bastion System of Fortifications, Its Defects and Their Remedies," in 1872. Mr. Holden resigned his commission in the army in March, 1873, to accept appointment as professor of mathematics in the U. S. Navy, for service as astronomer in the U. S. Naval Observa-

tory, Washington, D. C. Professor Holden was assigned to duty on April 15, 1873, as assistant with the transit circle, under Professor Harkness. The 26-inch refracting telescope of the Naval Observatory was completed in November, 1873, and on November 17 Professor Holden was transferred to that instrument as assistant under Professor Simon Newcomb. It is clear from historical developments, as well as from passages in Newcomb's "The Reminiscences of an Astronomer," that Newcomb was tremendously impressed with Holden's energy and ability. When Mr. D. O. Mills, president of James Lick's first board of trustees, went to Washington in 1874 to consult with Newcomb and others concerning plans for the Lick Observatory, Newcomb "suggested that a director of the new establishment should be chosen in advance of beginning active work, so that everything should be done under his supervision. As such director I suggested that very likely Professor Holden, then my assistant on the great equatorial, might be well qualified. * * * The necessity of choosing a director was not, however, evident, but communication was opened with Professor Holden as well as myself to an extent that I did not become aware of until long afterward."

It is an illuminating comment upon Professor Holden's promise as an astronomer of the future that he should be recommended, and probably tentatively selected, as the director of the proposed Lick Observatory, to contain the largest and most powerful telescope in existence, at a time when his astronomical experience had covered but little more than one year. Professor Holden was then less than twenty-eight years of age. The appointment referred to was not made, as the first board of trustees resigned in 1875, following certain unsatisfactory relations with James Lick, and a new board of entirely different personnel was appointed by Lick in 1876, under whose auspices the actual construction of the observatory was conducted. The appointment was actually made by the regents of the University of California on October 20, 1885, for service as director to begin upon the completion of the observatory, two or three years later.

Professor Holden continued as assistant with the 26-inch refractor under Professor Newcomb to May, 1875, and under

Professor Hall to February, 1880. In addition to assisting energetically with the principal programs of observation with this instrument, Holden undertook many pieces of work on his own account. He investigated the object glass and the micrometers of the great equatorial and published a brief description of the instrument. He observed the positions of the satellites of the planets; he observed especially interesting double stars; he made drawings of Mars, Jupiter, and Saturn, and of several especially interesting nebulae; he observed the surface markings of the planet Venus; he made position observations of the comets; and he made extensive observations of the Great Nebula in Orion. His monograph on the Nebula of Orion, based upon observations begun in 1874 and continued through many years, is the most extensive paper on the subject that has ever been published. It includes a painstaking résumé of all previous observations, his own observations of the positions and brightness of the principal details of the nebular structure, and a comparison of his results with the earlier observations. Holden expressed the hope that his work would be useful to succeeding astronomers when examining the object for evidences of motion or of variations in brightness. Before the monograph was published Dr. Henry Draper had made the first photograph of the Nebula of Orion, in September, 1880, and a full-page artotype reproduction of Draper's photograph of March 14, 1882, exposure 137 minutes, was included in the monograph. Although the photographic method of delineating such objects was then in its infancy, Professor Holden recognized some of the advantages of this method over the visual method of observation. The sequel has, indeed, shown that searches for motion and other evidences of change in the Orion Nebula will be based upon the photographic records alone. This is one of the penalties which the pioneers pay to progress.

The transit of Mercury which occurred on May 6, 1878, was observed by Dr. Henry Draper and Professor Holden at Draper's observatory in New York.

Professor Holden was in charge of an expedition dispatched by the Naval Observatory to Central City, Colorado, to observe the total solar eclipse of July 29, 1878. His part in the observ-

ing program consisted of a search by visual methods for the hypothetical planet Vulcan. All objects seen were identified as well-known stars.

Professor Holden was sent to London in 1876 as a delegate from the United States Government to examine and report upon the South Kensington Loan Collection of Scientific Instruments, especially as to improvements in astronomical and geodetical instruments.

While on the staff of the Naval Observatory Professor Holden made himself very familiar with the literature of astronomy. He prepared and published a very complete bibliography of papers and books relating to nebulae and star clusters, to the transits of Mercury, and to other subjects. He prepared annual reports on the progress of astronomy. He wrote many popular articles for the magazines and many semi-popular articles for scientific journals. In collaboration with Professor Newcomb, he wrote a text-book on astronomy for high schools and colleges. An abridged edition of the latter volume served for schools. He prepared and published (1881) a volume on "Sir William Herschel: His Life and Works"; and in collaboration with Professor C. S. Hastings he prepared and published (1881) "A Synopsis of the Scientific Writings of Sir William Herschel."

In February, 1879, Professor Holden was relieved in part from technical duty to serve as librarian of the U. S. Naval Observatory. For work of this kind Professor Holden possessed unique talents, and it is not surprising to read in the Superintendent's report, dated October 20, 1879, that the library "is now in a satisfactory condition." While engaged in cataloguing the library Professor Holden prepared a complete index to the publications of the Washington Observatory during its entire existence, from 1845 to 1875. He served as assistant on the transit circle under Professor Eastman from April 1, 1880, to January 1, 1881.

Professor Holden resigned the professorship of mathematics early in the year 1881 to accept appointment as director of the Washburn Observatory of the University of Wisconsin, in succession to Professor J. C. Watson, deceased. His activities at Madison are reflected in the publications of the Washburn

Observatory, volumes I to IV. They include observations of nebulae, double stars, red stars, comets, etc.; meridian observations of star positions, especially of the 303 stars in Auwers's Fundamental Catalog of Southern Stars; of investigations on the distribution of stars in the sky, based upon Sir William Herschel's star gauges and the principal existing star charts. In collaboration with Prof. J. G. Hagen, he prepared and published a catalogue of 1,001 stars from the observations of Tacchini in Palermo in the years 1867-'69.

The National Academy of Sciences organized an expedition to observe the total solar eclipse of May 6, 1883, in the Caroline Islands. Appropriations in support of the expedition were made by Congress and from the Watson Fund of the National Academy. Professor Holden was appointed chief of the observing party and scientific director of the expedition. Associated with him were four young astronomers whose names later became well known: Professor C. S. Hastings, Mr. E. D. Preston, Mr. S. J. Brown, and Mr. Winslow Upton. The experiences passed through by many eclipse observers in the tropics fell to the lot of the expedition to the Caroline Islands; the sky was clear during the greater part, but not all of totality, and during the partial phases there were clouds and rain. The air in most tropical localities is so near the saturation point that the fall of temperature when the moon is covering the sun is sufficient to cause clouds and precipitation; and that the sky is clear one moment does not mean that the following minute will not bring clouds and the following five minutes rain. Professor Holden's expedition was successful in carrying out all of the main features of the program. A search for the hypothetical planet Vulcan led again to negative results. Spectroscopic and polariscopic observations of the corona were secured as planned. The details of the corona were observed visually. The times of contact were estimated and the influence of the eclipse upon the meteorological elements was observed. The memoir on the eclipse of 1883 is a model in form and is frequently referred to by past and future observers of eclipses.

Professor Holden's connection with the Lick Observatory, University of California, is perhaps the most interesting and

important factor of his life. We have referred to Professor Newcomb's recommendation of his assistant, Professor Holden, for the position of director of the Lick Observatory. Professor Holden served extensively, but for the most part informally, and at all times without remuneration, as a scientific adviser to the Lick trustees during the organizing and construction period. Professor Newcomb's counsel was sought and freely given during the same period. Professor Holden visited Mount Hamilton in 1881 to assist in the installation of the meridian circle and to observe the transit of Mercury. He also visited Mount Hamilton in the fall of 1883, on the return trip from the Caroline Islands. It was upon the advice of Professors Newcomb and Holden that the atmospheric conditions on Mount Hamilton were tested by Professor Burnham in the summer of 1879. The trustees had delayed action on this subject until after the county of Santa Clara had constructed an excellent stage road from the Santa Clara Valley to the summit of Mount Hamilton, in fulfillment of their definite agreement with James Lick. The location of the observatory was, therefore, impossible of change after the road was built, but fortunately Mr. Burnham's report upon the observing conditions was enthusiastically favorable.

Professor Holden was appointed president of the University of California and director of the Lick Observatory on October 20, 1885, to serve in the former capacity until the observatory should be completed and thereafter in the latter capacity. His active service as president began about January 1, 1886, and as director of the Lick Observatory on June 1, 1888. Between these dates his interest in and service for the observatory were constant and of great value.

An astronomer has well said that "the first requisite for the director of a great observatory is to have a very clear notion of just what kind of work ought to be done, how it should be done, and then to give all the aid in his power to the investigator." Director Holden selected the most promising men he could find in the United States to comprise the observatory staff, and great credit must be accorded to his acumen, judgment, and courage in appointing several young men upon the basis of their contributions, as yet very limited in number and

extent. He assigned the members of the staff definitely to certain lines of research, which the future has shown to be of the highest importance. He gave them such opportunities to succeed as no other astronomers had ever enjoyed. In particular he gave them great liberty of action, wished them success, and the results of their work were published over their own signatures. To quote from Newcomb's *Reminiscences*, page 190:

"The institution made its mark almost from the beginning. I know of no example in the world in which young men, most of whom were beginners, attained such success as did those whom Holden collected around him."

The evidences of Professor Holden's organizing ability and energy are written all over the Lick Observatory. Nor were these qualities confined narrowly to the internal work of the institution. The total solar eclipse of January 1, 1889, was effectively studied, on his initiative, by a well-equipped expedition from the Lick Observatory. The *Astronomical Society of the Pacific* is truly his creation. The *Montgomery Library Fund* of the society, the *Donohoe Comet-Medal Fund* and the *Bruce Gold Medal Fund* were provided at his solicitation. He devised the unique regulations governing the bestowal of the Bruce gold medal, which insure that the award made by the trustees of the society shall be of unquestioned wisdom. In maintaining the relations of this observatory with other similar institutions throughout the world and in making the more important results of the observatory's researches known to the scientific public, Professor Holden gave devoted and able effort.

His own scientific work in the Lick Observatory related principally to the photography of the moon. He encouraged the study of his lunar photographs by astronomers in other institutions, and he published a lunar atlas comprising nineteen large sheets, the reproductions of enlarged photographs. He made occasional observations of the nebulae and of the planets. He was the editor of the *Publications of the Lick Observatory*, quarto, and of *Contributions from the Lick Observatory*, octavo. Three volumes of the former and five of the latter were issued during his residence at Mount Hamilton. His administrative duties did not leave much time for personal research.

The Lick Observatory had been planned and was essentially completed before astronomers realized that electricity and photography would become the chief servants in the great observatories. It was one of Director Holden's first duties to provide photographic equipment. The 33-inch correcting lens, to convert the 36-inch visual refractor into a 33-inch photographic instrument, was finished in 1888; the Willard-Crocker photographic telescope was completed in 1890; the D. O. Mills spectograph was provided in 1894; and the Crossley reflecting telescope was secured in 1895 and installed in 1896. An electric plant to supply current for purely scientific purposes was provided by gift of Thomas A. Edison in 1891. The instruments here noted were used by the members of the staff in developing several exceedingly fruitful fields of research.

Five expeditions were sent out by Director Holden to observe total solar eclipses: January, 1889, in northern California; December, 1889, in French Guiana; April, 1893, in Chile; June, 1896, in Japan; and January, 1898, in India.

The last years of Professor Holden's administration were marred by the existence of animosities in the observatory community and by much ill-advised criticism in the newspapers. The time has not come for any member of the staff under his administration to attempt a critical analysis of the situation, and I shall let a distinguished non-partisan speak. To quote again from Newcomb's *Reminiscences*, pages 192-193:

"The term of Holden's administration extended through some ten years. To me its most singular feature was the constantly growing unpopularity of the director. I call it singular because, if we confine ourselves to the record, it would be difficult to assign any obvious reason for it. One fact is indisputable, and that is the wonderful success of the director in selecting young men who were to make the institution famous by their abilities and industry. If the highest problem of administration is to select the right men, the new director certainly mastered it. So far as liberty of research and publication went, the administration had the appearance of being liberal in the extreme. Doubtless there was another side to the question."

Professor Holden's astronomical career practically terminated with his departure from Mount Hamilton in October, 1897. He resided in New York city until the latter part of 1901, where much of his time was devoted to the writing of

popular articles and books on astronomical subjects of everyday interest.

From November, 1901, until his death he was librarian of the United States Military Academy at West Point, New York. When his former associates heard of this appointment they said without hesitation: "He will be wonderfully successful," and so it seems he was. In 1907 the well-known journal, *Army and Navy Life*, inaugurated a series of biographies of "Distinguished Graduates of the United States Military Academy in Civil Life," by beginning "this series of articles with a brief survey of the distinguished career of the Academy's most learned living alumnus, Dr. Edward Singleton Holden," prepared by Capt. E. G. Davis, U. S. A. I shall let Professor Holden's biographer speak of his services to the library of the Military Academy:

** * * He has labored unceasingly, within the means at his command, to make the library meet the legitimate needs of every instructor and every cadet.

"He saw from the first the magnitude of this last great task which he has undertaken. He found the library fairly well supplied with books on every subject, but their contents were not readily available. His first task was to complete the collection, so that every subject is now represented by the standard books that give its past history, as well as by the current periodicals which exhibit its present progress. Some 30,000 volumes have been added to the library since 1901. * * *

"All the new books of the library and all the military books, whether new or old, have been thoroughly catalogued and made available to instructors and others. A veritable mine of information has been opened for them in which they can find unlimited material for the extension of their professional studies or for original research in any field.

"Every nook and cranny of the library has been ransacked and Doctor Holden has personally examined every paper in the records of the bureaus of the War Department from the beginning of 1838 (the date of the fire which destroyed the records at West Point), making copies of all the important MSS. So that now for the first time since 1838 the historical records at West Point are substantially complete. Many orderly books, etc., have been acquired by gift or purchase.

"All of this material has been catalogued and much of it has been thoroughly gone over, either by Doctor Holden himself or under his direction by officers who have voluntarily assisted him in this work. * * *

"His report as librarian for the last year shows that about twenty-five per cent of the younger officers did volunteer work for the library and that more than one-third of the officers of the post were there engaged in serious work and many more at their own quarters. * * *

"Recently an officer, who was to deliver a lecture to the student officers at a near-by post, wrote to Doctor Holden asking for assistance in the collection of historical data concerning the development of a particular military subject.

"'Visit the library,' replied the Doctor, 'and all our books and manuscripts relating to this subject will be placed at your disposal.'

"The officer came. He found a table piled high with books and papers, containing, perhaps, every treatment of the subject from the time of the Greeks and Romans down to the present. He was inclined to despair when he saw the mass of material before him. To wade through such a pile of books seemed an endless task. But to his astonishment he found that the work had been more than half done for him; he was furnished with a manuscript bibliography of his subject, which gave him in a moment just what the various books contained and told him where to look for it. He went away delighted and enthusiastic. Doctor Holden has prepared similar complete bibliographies on every military subject. As soon as funds are available they are to be printed and distributed to the service. When this is done officers will know just what data are available for the study of any military subject in which they may be interested."

Professor Holden's interests took a wide range. He has written and published on the bastion system of fortifications; on the number of words used in speaking and writing; on the celebrated cipher dispatches of 1876 relating to the election of a President of the United States in that year; on the treatment of pamphlets in special libraries; on studies in Central American picture writing; on a system of local warnings against tornadoes; "The Mogul Emperors of Hindustan," a delightful volume published in 1895; a volume on "Mountain Observatories in America and Europe" (1896); a volume of "Memorials of W. C. and G. P. Bond" (1897); a "Catalogue of Earthquakes on the Pacific Coast, 1769 to 1897" (1898); a volume entitled "Earth and Sky" (1898); "Our Country's Flag" (1898); a "Primer of Heraldry" (1898); "Elementary Astronomy" (1899); a volume on the "Family of the Sun" (1899); "Essays in Astronomy" (1900), by various authors, including three by himself; "Stories of the Great Astronomers" (1903); "Real Things in Nature" (1903); "The Sciences" (1903); the "Centennial History of the United States Military Academy, 1802-1902," Vol. II, containing a full bibliography of West Point for 1524-1902, of the Military

Academy for 1776-1902, and of the writings of all graduates of the Military Academy during 1802-1902. There are many magazine articles on still other subjects.

Distinguished honors were bestowed upon Professor Holden. He was elected foreign associate of the Royal Astronomical Society in 1884; a member of the National Academy of Sciences in 1885; and later to membership in the Astronomical Society of France, in the Italian Spectroscopic Society, in the American Academy of Arts and Sciences, in the American Philosophical Society, etc. He received honorary degrees: M. A. from Washington University in 1879, LL. D. from the University of Wisconsin in 1886, LL. D. from Columbia University in 1887, Sc. D. from the University of the Pacific in 1896, and Litt. D. from Fordham College in 1910. He served as a member of the board of visitors to the United States Military Academy in 1885, and of the board of visitors to the United States Naval Academy in 1896. The reports of the boards of visitors for those years were live documents. He was made a knight commander of the Ernestine Order of Saxony in 1894, and a knight of the Royal Order of the Dannebrog in 1895, and the Order of Bolivar was conferred upon him in 1896.

Professor Holden possessed abilities wonderful in many ways. His knowledge of literature, both general and scientific, including, of course, the literature of astronomy, was very extensive, and this knowledge appeared always to be at his immediate command. He enjoyed writing; he wrote rapidly and with a fine literary style. It is a remarkable fact that the heavy correspondence of the Lick Observatory was conducted by Professor Holden's personal pen throughout his term of office. He did not utilize the services of a stenographer and only an occasional letter was copied with the typewriter. His social abilities were of very high order. His conversation was entertaining to the point of brilliancy. His hearers did not always agree with his point of view, which he defended with vigor and skill, but no one could be found to deny that Professor Holden had made the subject seem alive. His lamented death on March 16, 1914, marked the passing of an extremely interesting man.

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Very truly yours:
J. M. Billings.

NATIONAL ACADEMY OF SCIENCES
OF THE UNITED STATES OF AMERICA

BIOGRAPHICAL MEMOIRS
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BIOGRAPHICAL MEMOIR

OF

JOHN SHAW BILLINGS

1838-1913

BY

S. WEIR MITCHELL

WITH

THE SCIENTIFIC WORK OF JOHN SHAW BILLINGS

BY

FIELDING H. GARRISON

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MEMOIR OF JOHN SHAW BILLINGS

BY S. WEIR MITCHELL.

It has been the custom of the National Academy of Sciences to commemorate in memoirs those whom death has removed from its ranks. Since the lives of men of science are little known except to those engaged in their own lines of research, some record is the more to be desired of one who illustrated the fact that scientific capacity may exist with varied ability for the conduct of large affairs. This combination of talents has been often found in the ranks of the Academy, although, in the belief of the public, the man of science is presumed to be incapable of the successful management of commercial business.

The many tasks to which his life of work summoned the subject of this memoir have become, since his death, for the first time so widely known that it is unnecessary for me to do more than to put on paper a brief summary of his career and the reasons for his election to this distinguished body of men of science, where from 1887 to 1899 he rendered efficient service as our treasurer and served on eight important committees or as a member of our council. The life of our fellow member in fact needs less restatement from us because since he died at least a half dozen men of importance have recorded their opinions of this attractive and much-loved man and of what he effected during his ever busy existence. Moreover, a full and competent biography has been undertaken and will, I am sure, do ample justice to one who owed nothing to newspaper notoriety. Through his modest life of the labor he loved he accepted grave burdens and whatever duties, official or other, fell to him, apparently indifferent to praise or popular reputation, while he dealt victoriously with tasks so various in their nature that any one of them would have sufficed to tax the technical competence of the most able man.

JOHN SHAW BILLINGS was born in Switzerland County, Indiana, April 12, 1838. From the time he went to college until after the end of his medical studies he was almost entirely

without exterior aid. He was graduated from Miami University in 1857; A. M. in 1860. His personal struggle for a college education and the sacrificial privations by which he attained his medical degree in 1860 from the medical college of Ohio will, I trust, be told in full elsewhere. He won his way unhelped by taking charge of the dissection rooms and for one entire winter, as he assured me, lived on seventy-five cents a week, as he believed to the serious impairment of a constitution of singular vigor.

Hospital service gave him what the imperfect medical teaching of that day did not give, and, as demonstrator of anatomy, he prepared himself for surgical practice, which was to find its opportunities in the clinics of the battlefield.

In the year 1861 came one of the many periods for decisive choice he was to encounter as life went on. A certain career as assistant to a busy surgeon was offered him. His strong sense of duty to his country made him decline the tempting opportunity and he entered the regular army first of his class in a competitive examination and was commissioned Assistant Surgeon, U. S. A., April, 1862.

To deal briefly with his army career, he became Surgeon-Captain in 1866, Surgeon-Major in 1876, and Colonel and Deputy Surgeon-General in 1890. He was retired from active service in 1895 by President Cleveland at his own request and through the influence of the University of Pennsylvania, which at this time offered him the place of professor of hygiene.

During the war he was breveted Major and Lieutenant-Colonel for faithful, gallant, and meritorious service. Dr. Billings won in the field a high reputation as a very skillful and original operative surgeon, and a character for courage and resourceful administrative ability on many occasions, but especially when after the disastrous battle of Chancellorsville he conducted the retreat of the wounded, and when later he was actively engaged in perilous service during the battle of Gettysburg.

During his army service he began very early to exhibit his constructive talent in altering or building hospitals, and his remarkable power of administrative command in these vast homes of the sick and wounded.

Without dwelling too much on this part of his career, I may say that there were many months of service in the field and also as an Acting Medical Inspector of the Army of the Potomac. Dr. Billings' war service with the army ended when, in December, 1864, he was ordered to Washington, where he had charge of the Invalid Reserve Corps, of matters relating to contract surgeons, and a variety of other business.

Some time in 1864 he was sent by the President with others to the West Indies on an errand connected with the futile plan for deporting some of our recently made freedmen to an island. This scheme appears to have failed, as might have been expected, and probably the expedition in which he was included was meant to bring back the men previously thus deported. It was a somewhat fantastic scheme, and I do not find any account of it in the histories of the war. Probably Dr. Billings had an important share, for here, as elsewhere, no matter what his relation was to a body of men and officers, his peculiar talents soon found their influential place.

It becomes clear from what I have already said that his capacity to turn with ease from one task to another must have become by this time very well known to his superiors. His own desire was to return to the field, but the promise to so indulge him probably failed owing to the somewhat abrupt termination of the war. Meanwhile he was required to deal with the voluminous medical reports sent in by the medical staff of the Army of the Potomac. The records of this work and of his other more individual surgical contributions are scattered through the voluminous medical and surgical history of the war. Here, as elsewhere, he left in these papers his mark as a man of many competencies.

Some of the duties to which he was assigned before his retirement were curiously outside of the work of a military surgeon, and he seems to have been lent by the War Department for a variety of governmental services. Thus while busy with the early work in connection with the museum and library, he was also occupied with the organization of the United States Marine Hospital Service in 1870. In 1872 he was Vice-President of the brief-lived National Bureau of Health, and was for a long period in charge of the division

of vital statistics of the eleventh census of the United States. During his career as a surgeon in the years before 1895 he became an authority on military medicine and public hygiene and revived his interest in hospital construction, to which he had given a great deal of thought. He was one of five who submitted in 1875 by request plans for the construction of the Johns Hopkins Hospital. His careful study of the conditions required in a hospital were accepted. They included many things novel at that time which it is not needful for me to dwell upon here, but some of them were very original changes from the organization and construction to be found in hospitals at that period.

During these years he went to Baltimore from time to time and lectured on the history of medicine and on hygiene. He also supervised the planning and construction of the Barnes Hospital of the Soldiers' Home, Washington, D. C., and later the buildings needed for the Army Medical Museum and the Surgeon-General's library. His final constructive work late in life was his connection with the plans for the Brigham Hospital in Boston and during many years he was continually consulted by institutions or cities in regard to hospitals and hygienic questions of importance.

The great work of John Shaw Billings which gave him finally a world-wide repute began at some time after 1864, when he was asked by the Surgeon-General to take charge of the Army Medical Museum created under Surgeon-General Hammond by the skillful care of Surgeon John H. Brinton. His formal assignment "in charge of the Museum Library Division and as curator of the Army Medical Museum" dates from December 28, 1883, but he had been informally librarian for many years before that time. It is quite impossible here to enter into any detailed account of the ingenuity and power of classification which has made this museum the greatest presentation of the effects of war on the bodies of men. It is, however, essential to say a few words about the varied capacities which built up and made finally available to scholars the library of the Surgeon-General, now the most completely useful collection of medical works in the world.

In some reminiscences of his younger days he speaks of his student aspiration "to try to establish for the use of American physicians a fairly complete library, and in connection with this to prepare a comprehensive index which should spare medical teachers and writers the drudgery of consulting thousands or more indexes or the turning over the leaves of many volumes to find the dozen or more references of which they might be in search." The opportunity he craved when young came now by singular good fortune into his possession. When he took hold of this work the Surgeon-General's library contained a little over a thousand volumes and all interest in its increase had been long at an end. Fortunately, as I so understand, at the close of the war there fell into the hands of the Surgeon-General some eighty-five thousand dollars, the result of hospital savings during the great contest. He was allowed to use this money for the building up of the museum and of the library, which was an essential adjunct to the collection. It was a vast piece of good fortune that this task fell to the man who had craved such a chance since his youth. He brought to it powers which are rarely united in one man and an amount of knowledge of books, medical and non-medical, which few possess. When he was nominated for membership in the National Academy of Sciences his claim to this high distinction was judiciously founded by his friends upon his application of skill in the scientific classification of books and of the medical knowledge of our profession through the centuries. No medical librarian who ever lived had, up to that time, shown such an almost instinctive capacity for the scientific classification of knowledge so as to make it readily available. It was eminently a scientific gift and of incredible usefulness in its results to the scholarship of medicine throughout the world.

When he gave up this charge at the time of his appointment to the chair of hygiene in the University of Pennsylvania, he received from the physicians of Great Britain and America at a dinner given in his honor a silver box containing a check for ten thousand dollars, as a material expression of gratitude for the labor-saving value of his catalogue.

The surplus of this fund enabled his friends to present to the Surgeon-General's library an admirable portrait of John Billings by Cecelia Beaux.

The library as he left it contained 307,455 volumes and pamphlets and 4,335 portraits of physicians. At the present day in the skillful hands which took up his task it has reached over half a million volumes and over five thousand portraits and has a unique collection of medical journals quite matchless elsewhere.

He went about the preliminary measures for the catalogue with cautious care and in 1876 prepared a specimen fasciculus of the proposed catalogue of the library, consisting of a combined index of authors and subjects arranged in dictionary order, and submitted it to the profession for criticism. In this he was aided by his able assistant, Dr. Robert Fletcher. In the first series of the index catalogue, 1880-1895, the material was selected and a scientific classification made by Billings. The future of the library has been entirely in the hands of men at first chosen by him and always ever since by medical officers of distinction. As a monthly supplement to the index catalogue, the *Index Medicus* was begun by Dr. Billings and Dr. Fletcher in 1879 as an extra official publication. When, in 1903, the second series of the *Index Medicus* was started it was seen that there was a risk of failure in this invaluable publication through want of means, but at this time by his influence through the aid of the Carnegie Institution of Washington, it was permanently established at the cost of some twelve thousand dollars a year and continues to be a helpful aid to scholarly physicians all over the world.

It was here that Dr. Billings got his training for the still larger task which awaited him when he was chosen as librarian of the Astor-Tilden-Lenox Library in New York. There at once this great enterprise found in him all the varied qualities which were needed in the construction of the building, the classification of its contents, the efficient administrative grasp on the forty outlying libraries of New York connected with the triple library, and in his singular power of uniting strict discipline with a capacity to attach to him those under his control.

Throughout his life he was a busy writer of essays on hygiene, hospital construction, and administration, the statistics of war and addresses or essays such as his history of surgery, perhaps the best presentation of this subject ever made.

To comprehend the character of a man, he must have been seen in his relation to the various duties which test the qualities of both heart and head. The charge of suffering, crippled, wounded soldiers is a trial to the surgeon and here he showed the man at his best. He was patient with the impatient, never irritable with the unreason of sufferers, never seeming to be in a hurry, and left at every bedside in the long, sad wards the impression of being in earnest and honestly interested.

It was thus I first knew John Billings when in the crowded wards wearied, homesick men welcomed his kindly face and the almost womanly tenderness he brought to a difficult service.

My own personal relations with John Billings began early in the Civil War, when he had for a long time the care of my brother, a medical cadet, during a mortal illness contracted in the Douglas Hospital, Washington. I saw then how gentle-minded was this man and how he realized the pathetic disappointment of a highly gifted young life consciously drifting deathward. I saw thus a side of John Billings he rarely revealed in its fullness. Generally a rather silent man, he was capable now and then of expressing in eloquent brevities of speech the warmth of his regard for some one of the few he honored with his friendship. In the last talk I had with him he said to me some things which remain as remembrances of this rather taciturn and reserved gentleman. I had asked him how many degrees and like honors he had received and, considering these notable recognitions, I remarked on the failure of popular appreciation. He replied with a jesting comment and then said, after a brief silence, that he was far more proud of his capacity to win the friendship of certain men and of the service he had been able to render to science in his connection with the Carnegie Institution of Washington. There, indeed, his always wise and broad-minded interest will be greatly missed. I served with him from its foundation on the distinguished executive committee of this body. Here, among men he liked and trusted, we saw him at his familiar best. Always

a patient listener, his decisions as chairman were expressed with his quiet, courteous manner, and many times his large knowledge of the science of the day left me wondering how it could have been attained amid the amazing number of occupations which had filled his time. But in fact he was intellectually sympathetic with *every* form of scientific research—a somewhat rare characteristic among investigators. I ought also to say that the men of our committee and of the board of trustees felt at times a little surprise at the shrewdness, the common sense, and the commercial insight he brought to the critical financial consideration of this immense money trust. Not elsewhere was he better seen or understood as conveying the sense of character, and nowhere else was he better loved.

Numberless presidencies of societies fell to his share, and the list of his honorary titles from all of the greater academies and universities at home and abroad served at least to show in what esteem he was held by men of science. These recognitions gave, I suspect, more pleasure to his friends than to this retiring and singularly unambitious scholar.

On public occasions his personality stood for something in the estimate of the man. Tall and largely built, he was as a speaker in the after-dinner hour or when addressing a body of men a commanding presence, with flow of wholesome English, ready wit and humor such as rarely came to the surface in his ordinary talk. The figure of athletic build, the large blue eyes, a certain happy sense of easy competence, won regard and held the respectful attention of those who listened. For me there was always some faintly felt sense of that expression of melancholy seen often in men who carry through a life of triumphant success the traces of too terrible battle with the early difficulties of their younger days.

What was most exceptional in this man was the unfailing fund of energy on which he drew for every novel duty, and an industry which never seemed to need the refreshment of idleness. He had that rare gift—the industry of the minute. When once I spoke of the need for leisurely play and the exercise of open-air sports, he said that he obtained recreation by turning from one form of brain use to another. That was play enough. I ought to add that he found pleasure in read-

ing novels, saying that one or two of an evening late were agreeable soporifics. But these, like more serious books, he devoured rather than read as most men read, and what he read he seemed never to forget. His memory was like a good index of a vast mental library.

Until his later years Dr. Billings possessed the constitutional vigor which befriended him earlier as he responded to the call of a succession of military and civic duties. Of late years he was obliged to undergo several surgical operations of serious nature. He went to them with confidence and courage, but before the last one he said to me, "I am for the first time apprehensive." He went on to add, "It is a signal of age; and of late, as never before, any new project, any need for change in the affairs of the library, I find arouses in me an unreasonable mood of opposition. This, too, is, I know, a sure evidence of my being too old for my work. I shall, I think, resign my directorship of the library." It was our last intimate talk. He died of pneumonia after the operation, on the eleventh of March, 1913.

The scene at his burial in the military cemetery at Arlington brought together many men of distinction, a much moved group of army men and the great library officials. We left in the soldier burial ground all that was mortal of a man who combined qualities of head and heart such as none of us will see again.

Dr. Billings married Miss Kate M. Stevens in September, 1862. Their children are: Mary Clure, Kate Sherman, Jessie Ingram, John Sedgwick, and Margaret Janeway.

Science is forever changing. The work of today is contradicted tomorrow. Few, indeed, are so fortunate as to leave in the permanent remembrance of science conclusive work. The man whose loss we regret left to medicine in his catalogue of the Surgeon-General's Library a monumental labor which none will ever better and to which he gave continuity of vigorous life.

THE SCIENTIFIC WORK OF DR. JOHN SHAW BILLINGS

BY FIELDING H. GARRISON, M. D.

JOHN SHAW BILLINGS, perhaps the most versatile American physician of his time, achieved excellence and gained distinction in no less than six different fields—in military and public hygiene, in hospital construction and sanitary engineering, in vital and medical statistics, in medical bibliography and history, in the advancement of medical education and the condition of medicine in the United States, and as a civil administrator of unique abilities.

Shortly after receiving his medical degree from the Medical College of Ohio (1860), Dr. Billings prepared to enter upon surgical practice in Cincinnati, where his prospects were excellent, but the outbreak of the Civil War turned his mind to the larger service of his country, and, in September, 1861, he passed his examination before the examining board for admission to the Medical Corps of the United States Army and was duly commissioned First Lieutenant and Assistant Surgeon on April 16, 1862. As an army surgeon his services were continuous and included some twenty-one months' work in hospital and a full year of roughing it in the field. He long afterwards described this experience as his postgraduate course in surgery, "with its service in camps and hospitals, with battle-fields for the great clinics—a long, weary course." During the Civil War his reputation for courage and ability was of the best, and the end of the great struggle found him one of the medical inspectors of the Army of the Potomac, with a brevet of Lieutenant-Colonel "for faithful and meritorious services" (1865). Being in charge of Cliffburne Hospital, near Georgetown, July 3, 1862, assisted by fifteen Sisters of Charity, he took care of many Union and Confederate wounded from the seven days before Richmond, and did nearly all of the operating. At Chancellorsville, he and his assistants worked night and day, under artillery fire, in feeding and taking care

of the wounded; at Gettysburg, his experiences were the same, and in both battles he did an enormous amount of surgical work. During the war he performed nearly all the major operations done in the pre-Listerian period, and he was the first surgeon in the war to attempt the rare operation of excision of the ankle joint (January 6, 1862), which had been done only two or three times before in the history of surgery, and was completely successful in his case. Lister's classical paper on excision of the wrist, a landmark in the surgery of the joints, was not published until 1865.

On August 22, 1864, having been disabled during the long siege of Petersburg, he was relieved from duty in the field and assigned to the Washington office of the Medical Director of the Army of the Potomac, where he assisted in the redaction of the field reports, which were subsequently embodied in the Medical and Surgical History of the War. On December 27, 1864, he was transferred to the Surgeon-General's Office of the War Department, where he was to remain for thirty years, up to the date of his retirement from active service in the army, October 1, 1895. Here his real life work began. Prior to this period his only contribution to scientific literature was a graduating dissertation on epilepsy, already notable for clear-headed common sense and a certain quaint vein of humor. His most important contributions to medical science were made during the thirty years of his incumbency as librarian of the Surgeon-General's Office.

Upon assuming his new duties at the beginning of 1865, Billings threw himself into the dry details of departmental routine in his cool, imperturbable way, and during the next five years he was principally occupied with the official drudgery connected with the business of disbanding the great body of acting assistant surgeons of the war, dismantling the military hospitals, and winding up the financial accounts of both. In this period he read assiduously, wisely, and well, and applied himself with zest to microscopic work, which was then coming into fashion in this country. After casting about in various directions, he settled down to the investigation of the minute fungi, of which he published two studies in the *American Naturalist* in 1871, and at the same time made a valuable

private collection, which he long after presented to the New York Botanical Garden in 1902. Meanwhile, in 1869, he had collaborated with his army colleague, Dr. Edward Curtis, in a special report on the possible cryptogamic origin of the Texas fever and pleuropneumonia of cattle. The object of this research was to ascertain if the so-called cryptogamous diseases of cattle were caused by the "micrococcus of Hallier." The findings were negative and the investigation is null today. Significant, however, is the prophetic statement that, in establishing a causal relation, the lancet and injection tube would probably accomplish more than the microscope and culture apparatus.

About this time Dr. Billings entered upon his career in public and military hygiene. During 1869-'74 he was detailed, under the Secretary of the Treasury, to inspect and report upon the status of the Marine Hospital Service, which was then sadly in arrears on account of the poor administration incident to bad political appointments. In this relation, Billings traveled over the length and breadth of the country. His recommendations, based upon what he saw during his tours of inspection, were adopted and the value of his services acknowledged by the Secretary of the Treasury as follows: "The condition of the marine hospitals has been improved during the past year. This result is largely due to Dr. J. S. Billings, of the Surgeon-General's Office, who has visited nearly all of them, and through whose advice many important changes have been made."¹ The principal thing he did for the service was to take it out of politics and give to it the military methods of organization. Known as the Public Health Service since 1912, this branch of the Government now works hand in hand with the medical establishments of the Army and Navy in the advancement of preventive medicine.

In 1870 and 1875, Dr. Billings made two reports to the Surgeon-General upon barracks and hospitals and upon the hygiene of the United States Army. These became classical, at least as far as our own military establishment is concerned. In the first monograph, now known as Circular 4, he collated

¹ Rep. Sec. Treasury, Washington, 1870, p. xii.

and edited some 527 pages of reports from medical officers on the barracks and hospitals of "the best fed and worst housed army in the world." His criticism of these hospitals is drastic and was the basis of his future work as a hospital constructor. He describes the pictures of U. S. Army hospitals in the report as "simply inserted as ingenious modes of 'how not to do it'"; but he recognizes that, in a country of such wide extent as ours, hospital plans must suit the climatic exigencies of "the burning mesas of Arizona and the bleak north Atlantic coast." His main contention throughout is against the false economy which results in "a saving in boards and brick at the expense of the health of the soldier." Circular No. 8, Dr. Billings's report upon the hygiene of the United States Army, is, in effect, a strong brief in aid of improving the health and personal well-being of the enlisted man. Bath tubs and shower baths, abundant space and good ventilation in quarters, a ration at least twenty-five per cent in excess of what is required, plenty of ice at Southern posts, lime juice and baking powder for scouts, canned tomatoes where fresh vegetables are not available, are recommended as novelties; and it is especially urged that the chief cook at a post should be a permanent detail, in place of the then custom of changing company cooks every ten days; that schools for instruction of cooks should be established at recruiting stations and a manual of cookery, with dietetic tables and culinary directions for all climates and seasons, prepared. The report concludes with timely observations on the ventilation, hygiene and avoidance of infection in the military hospitals. As part of Billings's work in military medicine should be mentioned his "Notes on Military Medicine in Europe" (1882), his report to the International Medical Congress at Berlin on international uniformity in medico-military statistics (1890), and his address on "The Military Medical Officer at the Opening of the Twentieth Century" (1903). Shortly before his retirement from the army, Dr. Billings became professor of military hygiene in the newly established Army Medical School at Washington (1894).

About 1874, Dr. Billings began to be active in the affairs of the American Public Health Association, of which he was made president in 1880. To its annual reports he contributed

papers on the effect of mountain climate upon health (1874), on hospital construction (1874), on medical topography (1875), on a plan for a systematic sanitary survey of the United States (1875), on community rights, duties, and privileges in relation to public health (1876), on a sanitary survey of Memphis, Tennessee (1879), and others. These titles all connote pioneer hygienic work of the most advanced type, for it must be remembered that there were no uniform quarantine regulations in the United States before 1893, and that before 1901 only ten States of the Union had even a satisfactory system of vital statistics. The truth is that until recent times the advancement of public hygiene in all countries and at all periods of the world's history has been fitful and capricious, always lagging behind the general trend of progress and usually following in the wake of some devastating epidemic disease. The despised Middle Ages, for instance, had a really impressive array of municipal laws and ordinances, hastily improvised against the scourges of pandemic leprosy, bubonic plague, and syphilis, as we have only just begun to learn through the extensive historical researches of Haeser and Sudhoff. Modern Europe was awakened to an interest in preventive medicine through the great cholera epidemic of 1830 and the three visitations of the same disease which followed successively upon each other during the decades 1840-'70. The splendid system of sanitary legislation of England, the best and most progressive in the modern world, started with the cholera epidemic of 1840-'50, which also occasioned the first sanitary survey in America—that of the State of Massachusetts in 1849. In Billing's time the immediate incentives to progress in sanitation were the yellow fever epidemics of 1878 and 1879. These occasioned, among other things, the foundation of the short-lived National Board of Health (March 3, 1879), an attempt at a Federal organization of which Dr. Billings was appointed vice-president at the start, and which died out through lack of congressional appropriations in 1886. Its powers had been enlarged by the National Quarantine Act of 1879; its personnel included some of the best men of the time, its transactions give abundant evidence of good and arduous work, but such an infantile organization, described by

Billings himself as "a premature birth," could not survive the inevitable struggles with the State authorities as to local quarantine, and its place has been very adequately taken by the present U. S. Public Health Service. The scientific work of the National Board of Health included the investigation of yellow fever in Cuba by Sternberg, Guiteras, Chaillé and Hardie, Professor Ira Remsen's investigation of organic matter in the air, the sanitary surveys of New York harbor and Memphis, Tennessee, and Billings's reports on nosology, the proper nomenclature of diseases in relation to the registration of vital and medical statistics. This matter, which was the starting point of Billings's remarkable labors on the United States census, as also of his classification of diseases in the Index Catalogue and Index Medicus, occupied his time and attention for many years. It was one of his main ambitions to establish a definite system for the registration of deaths and diseases in this country and to have it standardized in the several States, because he saw clearly that this would be the first step towards standardizing the status of physicians who might presume to make certificates as to the cause of death and the nature of the disease in each case. At the International Medical Congress at London in 1881, and again at the annual meeting of the British Medical Association at Brighton in 1886, he spoke in a very definite and decided way of this crying deficiency in our national medical legislation. In 1881, the criteria for determining the ethical, professional, and scientific status of (sometimes self-styled) "physicians" were established in Illinois by the State Board of Health, and in Alabama by the State Medical Society, which also officiated as the State Board of Health. In relation to the subsequent advances which have been made by the American Medical Association and other bodies in elevating the status of physicians, of the medical schools which educate these physicians, and of the medical periodicals which are their organs of opinion, the early propagandism of Billings could be remembered. In his own day he was as one crying in the wilderness, for the tendency of the medical politicians of the time was not to level upward to a higher standard, but inevitably downward.

Another project which Billings had very much at heart was

the possibility of making a searching sanitary survey of the whole United States as the first step towards establishing a perfect system of sanitation in its different cities and communities, according to their special needs. This idea, to diagnose or blue-print the diseases of a community or country before attempting to treat or prevent them, originated with Hippocrates, the Father of Medicine, who, in his excursus "On Airs, Waters, and Places," was the creator of medical topography. In his "Remarks on Medical Topography," read before the American Public Health Association in 1875, Billings gives a history of the subject in this country. In 1672, the Welsh physician, Charles Clermont, had essayed a medical topography of England along the old Hippocratic lines. The first treatise of this kind relating to the United States was Lionel Chalmers' "An Account of the Weather and Diseases of South Carolina" (London, 1776); but the real pioneer of medical topography in America was the celebrated Daniel Drake, in his "Picture of Cincinnati and the Miami Country" (1813), which was the foundation of his great work "On the Principal Diseases of the Interior Valley of North America" (1850-'54). In this vast treatise, now a classic, Drake triangulates the whole Mississippi Valley as to topography, climate, meteorology, natural history, population, and diseases. In 1843, the medical section of the National Institute at Washington had prepared and circulated a schedule of inquiries in aid of collecting data of this kind, but the committeemen, sent from this body to the American Medical Association upon its foundation in 1847, reported failure in their efforts for the following significant reasons:

"First, the general apathy existing even in the minds of medical men on the subject of hygiene; and, second, the favorable opinions entertained by almost every one addressed by the committee of the healthfulness of his own locality. * * * The United States may be considered as a country in which no legislative enactments exist regulating its sanitary condition. For, with the exception of some municipal regulations forced from the necessity of circumstances upon the large cities, and a few of the first steps of legislation in one or two of the States, each individual is permitted to exercise his own free will in regard to hygienic measures, too frequently at the expense of great sacrifices of human life."²

² Repts. and papers Amer. Publ. Health Assoc., 1874-'5, N. Y., 1876, ii, 41.

In 1848, the Committee on Public Hygiene of the American Medical Association drew up a schedule of questions similar to the above and some interesting papers, by way of reply, were obtained from the larger cities of the country. Some of the State medical societies, particularly that of Pennsylvania, in 1855 also undertook to collect medico-topographical data through the county medical societies. But, as Billings remarked, it needed "but a brief examination of these records to prove that a comprehensive sanitary survey of a State will probably never be accomplished by a State medical society." "The most valuable contributions to medical topography in this country," he adds, "so far as regards completeness and as affording data for a science of the etiology of disease, are the reports made by the medical officers of the army descriptive of their several posts. * * * This is due to the fact that these reports give the statistics of disease and the meteorology of each post upon a uniform plan, and thus afford the means of comparison between different localities." Upon such a plan Billings, as chairman of the Committee on a Sanitary Survey of the United States (American Public Health Association, 1875), caused his experts to draw up a *questionnaire*, comprising upwards of four hundred searching queries bearing upon the geographical locale, climate, population, water supply, drainage, habitations, schools, hospitals, and prisons, cemeteries, public health and quarantine regulations, diseases and other features of a given community; and these were to be submitted to some 325 American cities and towns of 5,000 inhabitants or more. This plan, which Billings regarded as sufficient to establish "the foundations of a national public hygiene in this country," as setting in motion the machinery for a perfect system of sanitation, was tried out in two or three cities, but it was found that, by reason of the large number of leading questions and the difficulty of getting physicians to answer them, not to mention the expensive alternative of employing experts for this purpose, the project had to be abandoned, as in the initial attempt made in 1845-'7. The sentences in which Billings urges this project upon physicians and legislators are pregnant with meaning, expressive of his strong character and of the spirit in which his incisive mind

was to apply itself in its future grapplings with the deficiencies of the United States census.

"It has been an article of professional as well as popular belief since the days of Hippocrates that the study of prevailing diseases of different places, with reference to their local causes, is of great value, and that all work in this direction should be encouraged as much as possible. Many books and essays have been printed under the title of Medical Topography; and, to judge from the bibliography of the subject only, we might fairly suppose that a large amount of data—scattered and disconnected, it is true—has been obtained and recorded. But when we come to examine these papers in detail it will be found in most cases that, while topographical data are given, the medical part has been left out; that the majority of them refer to but one form of disease—the malarial—and to the conditions which affect its prevalence, and that the information in regard to this is vague and general. Even the most complete and satisfactory essays, with the exception of the army reports, rely upon mortality statistics alone; and these, no matter how complete, will not furnish the information necessary for a satisfactory investigation into the causes of disease, which is the one great object of medical topography. We want to know how many of a given populations have been sick, of what disease, and for how long. For this purpose the statistics of all diseases are not of equal importance, for we can expect no special advantage from knowing how many cases of venereal or delirium tremens occur in a given square; but we must, of course, record many facts for the same reason that the pearl-diver collects many oysters—because we do not know whether they are valuable or not. For instance, most persons would say that topography has no relation to cancer, and yet there are some curious coincidences with regard to its prevalence in limited localities. * * * These statistics can, of course, be obtained only by the aid of physicians; but to induce physicians to undertake such a task as this some sufficient motive must be presented.

"It must be remembered that the art, or the so-called practical part of public hygiene, does not specially pertain to the medical profession. Medical men have been foremost in urging attention to the prevention of disease, both on the part of individuals and the public, not because it is specially to their interest to do so, but because their sympathies are daily and hourly appealed to by the spectacle of human suffering which they know might have been prevented, but which they find difficult or impossible to relieve.

"Medical men see more or less distinctly that a properly organized system of State medicine or public hygiene would require from each of them a certain—and from many a considerable—amount of labor in keeping records and furnishing information, while no corresponding recompense is proposed. They are naturally unwilling to furnish information to and co-operate with persons in whose selection for the

position of health officer they have had no voice, and for whom they often have little respect; and this will continue so long as the medical profession is not consulted in the selection of State and municipal sanitary authorities. To undertake to ascertain for a large city the number of cases and the results of each form of disease is practically impossible. It is hard enough to obtain the statistics of causes of death with any reasonable degree of accuracy, since physicians, like other people, are not addicted to doing steady work without some compensation; but if, instead of all diseases, we devote our attention to a few, the prospect is not so hopeless. * * *

"By the comparison and study of the daily bulletin maps of the Signal Bureau we have learned somewhat of the paths, rate of travel, and phenomena of the air-whirlpools, and it is not impossible that we may yet, in like manner and by somewhat similar means, become acquainted with the course of certain diseases, and, if not able to prevent, can at least warn and avoid. * * *

"A satisfactory medical topography should have reference not only to the causation, but to the prevention and cure of disease. Change of locality, as a therapeutic agent, is coming more and more into use, especially as regards diseases of the lungs, rheumatism, etc.; but as yet physicians have no sufficient data to guide them in recommending given localities to their patients. * * *

"We must endeavor to ascertain what the French call 'the medical constitution of a place,' the results of epidemic influences which are not yet epidemics, and the modifications which these undergo in different localities. * * *

"In medical topography as a science there has been little advance for a thousand years, and so long as the present methods are pursued no great additions to our knowledge in this direction can be expected. Vague generalities and opinions must be replaced by specific information, and from square miles we must come down to square feet. The results which we now have can best be compared to those obtained by the young chemist who made an analysis of a rat—putting the entire animal into his crucible. The importance to a State or government of a complete topographical survey of its possessions has long been recognized; and much as has been done in this direction, it is now urged, by those most familiar with the subject, that in all of the States of this country a careful survey, with the preparation of maps on a large scale, similar to the work which has been done in England and Switzerland is necessary, and must sooner or later be effected. And it can hardly be doubted that in such surveys the prevailing diseases of each locality should be recorded as carefully as its geology, botany, or zoölogy."*

The address which Billings delivered as president of the American Public Health Association at New Orleans (Decem-

* *Ibid.*, pp. 50-53.

ber 7, 1880), was charged with the same sagacity and humor as the above and made a deep impression. In relation to the stationary character of the legal mind and the intrigues of medical politicians, he urges his fellow sanitarians to persevere bravely, even though "like Saul, the son of Kish, they go forth to find their father's asses, and they don't have to hunt long."

In November, 1879, Dr. Billings, in co-operation with Dr. Charles F. Folsom, Col. George E. Waring, Jr., and other members of the National Board of Health, made a sanitary survey of Memphis, Tennessee, following the epidemic of yellow fever in the city in the summer of that year. His recommendations were adopted and carried out at the instance of the original committee of fifteen appointed by the city itself, and his visit was described as "a moral tonic" in the local newspapers. He summed up his views of yellow fever in a remarkable article in the *International Review* of January, 1880. In this he points out that the probable cause of the disease is "a minute organism somewhat like the yeast plant, or it may be the product of such an organism, like alcohol"; that the clinical phenomena resemble those of snake bite; that yellow fever occurs near old wharves, piers, ships, wooden pavements, and other structures of decaying wood or in connection with huge piles of decaying seaweed, dead fish, etc., on the Gulf coast; that clouds of smoke from the burning of infected bedding in the streets are as the very wings of pestilence in conveying the infection, and that exposure and shaking of textiles in cold weather for three or four nights will avail to disinfect them. His citation of the old farmer's adage that "yellow fever can't go anywhere unless yer tote it," shows how close he was upon the theory of convection of yellow fever by mosquitoes.

During the twenty years preceding his retirement from active service in the army (1895), Dr. Billings was regarded as the leading authority on public hygiene in this country, and his services and advice were in request everywhere. During 1879-'83, he published in the *Plumber* and its successor, the *Sanitary Engineer*, a series of "Letters to a Young Architect on Ventilation and Heating," which were the basis of his "Principles of Ventilation and Heating" (1884), and were republished in enlarged form in 1893. In 1879, he furnished the in-

troductory chapter on hygiene and its jurisprudence to A. H. Buck's treatise (Ziemssen's *Handbuch*), which was the germ of two separate treatises on hygiene published in William Pepper's *System of Medicine* (1885, 1893). In connection with his general sanitary work, he wrote a large number of papers for the medical periodicals bearing on all aspects of the subject, *e. g.*, those on vaccination (1882), house sanitation in large cities (1882), heating and ventilation of a school building (1882), sewage disposal in cities (1885), water supply for small towns (1889), house drainage, a paper of great practical value for householders and housewives (1889), public health and municipal government (1891), municipal sanitary defects in American cities (1893), and studies of municipal sanitation in Washington and Baltimore (1893), New York and Brooklyn (1894), Boston and Philadelphia (1894). During 1876-'82, he gave expert opinion on the ventilation of the hall of the House of Representatives; his letter books reveal a vast amount of correspondence in which his unique knowledge and experience as a ventilating engineer were in constant evidence, whether for a private club in Baltimore or in the construction of a large hospital laboratory, museum or library. His early dream of making a sanitary survey of the United States was occasionally realized in such isolated cases as those of Memphis (1879-'80) and St. Augustine, Florida (1892).

During the late eighties, Dr. Billings was lecturing on hygiene at the School of Mines, New York, and, in 1889, he signed an agreement with the University of Pennsylvania to assume the directorship of the University Hospital on January 1, 1890, to prepare plans for a laboratory of hygiene after studying the best hygienic laboratories in Europe, and to assume the professorship of hygiene in the university. His lectures on hygiene and vital statistics began during the academic session of 1891-'2, the subject of bacteriology being treated by Dr. A. C. Abbott. Upon his retirement from active service in the army in 1895, he became full professor of hygiene at the university, continuing his lectures until June 1, 1896, when he became director of the New York Public Library. During his Philadelphia incumbency, he planned and

opened the Laboratory of Hygiene of the University (1892) and the William Pepper Laboratory of Clinical Medicine (1895). Among the memoirs of original investigations made in the Laboratory of Hygiene, which were presented to the National Academy by Billings, were the study of his pupil James Homer Wright on the bacteria of the Schuylkill River (1894), which led in some measure to the construction of the great Belmont filtration plant in Philadelphia; and the researches made by Miss Adelaide Ward Peckham on "The Influence of Light upon the Bacillus of Typhoid and the Colon Bacillus" (1894) and "On the Influence of Insolation upon Culture Media and of Desiccation upon the Vitality of the Bacillus of Typhoid, of the Colon Bacillus and of the Staphylococcus Pyogenes Aureus" (1894). Two other memoirs, published by the Smithsonian Institution, were "The Influence of Certain Agents in Destroying the Vitality of the Typhoid and of the Colon Bacillus," by Miss Peckham (1895) and "The Composition of Expired Air and Its Effects upon Animal Life," by Billings, Weir Mitchell, and D. H. Bergey (1895). Billings was in actual residence at the University of Pennsylvania for a period of eight months only. During his earlier career in hygiene he had belonged to the older or philosophical school of sanitarians, of whom Pettenkofer was the type, but the work done under his direction during his short Philadelphia period shows that he fully appreciated and understood the advances made by the newer or "bacteriological" school.

From the time of his celebrated report on the barracks and hospitals of the United States Army (1870), Billings had been specially interested in the subject of hospital construction. His real career as a practical expert and authority in this field, in which he made an epoch, began in 1876, when he was selected by the trustees of the Johns Hopkins Fund to be their medical adviser in the planning and construction of the hospital specified in the will of Johns Hopkins himself. On March 6, 1875, the trustees sent out a circular letter to five experts on hospital construction in the United States requesting plans for the proposed structure, and of these plans that of Dr. Billings was selected as the best, combining as it did the advantages of a central pavilion with detached buildings as hospital units, in-

cluding first-class physiological and pathological laboratories, a separate dispensary for out-patient relief and instruction of students, two pharmacies, and a training school for nurses. It was specified that the administration should be upon the military or railroad plan, under one head and one only; that clinical instruction should be given usually in the wards and out-patient department and not in any clinical amphitheater, except in the surgical unit; that medical cases should not be brought from beds to an amphitheater; that there should be graded accommodations for pay and private patients in rooms or suites of rooms; that a perfect system of records, financial, historical, and clinical should be kept, and that annual volumes of reports, made up of original scientific work, should be published. All these were absolutely new ideas in hospital construction and administration in this country, a fresh departure from the many-storied block hospitals of the past and the detached rambling wooden pavilions of the Civil War. The administrative ideal was not only the proper care of the sick poor, but graded accommodations for patients of different means and stations and, above all, the scientific education of physicians and nurses and the promotion of "discoveries in the science and art of medicine" and their publication. For some seventeen years, up to the opening of the Johns Hopkins Hospital on May 7, 1889, Billings labored over the revision and perfection of his original plans, frequently visiting the best European hospitals during his trips abroad, lecturing and advising with the trustees and university authorities as to ways and means of finance and administration, and conferring with President Gilman and Professors Welch, Remsen, and Newell Martin as to the curriculum of the future medical school. It was Billings who advised the selection of Welch and, five years later, of Osler as leaders of the medical faculty. The hospital, when completed and opened, was recognized everywhere as the finest in existence at the time. A full account of it will be found in Billings's "Description of the Johns Hopkins Hospital" (1890), which became a sort of textbook on the subject of hospital construction and ventilation, and is still used and consulted. In addition to the Johns Hopkins Hospital, Billings supervised the planning and construc-

tion of the Barnes Hospital of Soldiers' Home, D. C. (1873), the Army Medical Museum (1887), the Laboratory of Hygiene (1892) and the William Pepper Laboratory of Clinical Medicine (1895) in Philadelphia, the New York Public Library (1911) and the Peter Bent Brigham Hospital at Boston (1913). In the science of hospital construction he was entirely self-taught, as also in the complex details of sanitary engineering, in which his expert knowledge and skill were of the best order. He had a wonderfully keen eye for detecting the strong and weak points in any new set of plans and specifications just set before him. One stenographic report of his off-hand discussion of the plans proposed for the new City Hospital at Memphis, Tennessee (1897),⁴ is a remarkable example of his quickness in this regard. Of this phase of Billings's talents President Woodward of the Carnegie Institution (Washington) has remarked that "few engineers and few architects whom I have had the good fortune to meet could more quickly read a set of plans and specifications and hit upon the critical points to be considered."

Billings was one of the most accomplished statisticians of modern times, and with the late Gen. Francis A. Walker, who was superintendent of the ninth and tenth U. S. Census, perhaps the leading American authority on statistics in his day. On October 15, 1878, Billings transmitted, through Surgeon-General J. K. Barnes, a letter sent to the Honorable S. S. Cox, chairman of the Committee of the Census of 1880, in which some very valuable suggestions were made as to the advisability of including medical statistics, particularly those of disease-incidence, along with the data usually given as to births and mortality. He cites the experience of the Royal Sanitary Commission of England that, "however complete the registration of deaths may be, it cannot give a fair estimate of the sickness which is not fatal, it cannot indicate where or how these are to be prevented, it cannot tell the cost which is worth incurring for their diminution." At this time, it appeared that the only countries which attempted to obtain a registration of disease in connection with the national census

⁴ Memphis Med. Monthly, 1897, xvii, 193, 249, 309.

were Ireland, where a record of diseases with which individuals might be suffering on the day of the count was made in the patient's own words, often in Irish; and Portugal. The chief obstacle to the making of such records was that the questions had usually to be put and answered by unprofessional men. Billings suggests a series of questions eliciting information as to the number of days the person is unable to follow his avocations or attend school through the year on account of disease or injury, the disease or injury from which the person might be suffering on the day of the count, the mode of treatment, whether private, public (charitable) or in hospital, the particular incidence of specific infectious diseases during the year, if any, and data as to loss of wages and cost of medical attendance, medicines, and nursing. From this time on (1878-1912), Billings was active and prominent in the supervision of the vital statistics of the Tenth, Eleventh, and Twelfth Census of the United States (1880-1900). Of this phase of his work a competent reviewer in the *London Times* (July 22, 1915), states that: "Before 1880, when Dr. Billings took charge of the vital statistics of the United States Census, they were worse than worthless. For three decades—the Tenth, Eleventh, and Twelfth Census—Dr. Billings was a volunteer worker in this field of statistical inquiry, and from a state of chaos he brought the vital statistics of the United States to their present satisfactory condition."

Billings's reports on the mortality and vital statistics of the Tenth Census (1885-'6) consist of two stout volumes, with an atlas of plates and diagrams. In these reports, the figures furnished him were subjected to modern methods of analysis and interpretation and new data as to racial equation and race-incidence in disease were elicited by processes of statistical induction. Some of these data have been uniformly quoted in modern text-books on practice of medicine. In 1880, Billings had suggested that the various statistical data of the living and the decedent "might be recorded on a single card or slip by punching small holes in it, and that these cards might then be assorted and counted by mechanical means according to any selected group of these perforations."* This suggestion was

* Proc. Amer. Assoc. Adv. Sc., 1891, Salem, 1892, xl, 407-409.

taken up and applied by the inventor, Mr. Herman Hollerith, in the electrical counting and integrating machines which are now employed by the United States Census. Billings also introduced new wrinkles as to the modes of tabulation of vital statistics and the use of circles with multicolored sectors to represent various aspects of mortality and disease incidence. At the Tenth International Congress at Berlin (1890), he proposed a definite scheme for securing international uniformity in medico-military statistics. In connection with the Eleventh Census (1890), he made valuable special reports on the vital statistics of the Jews in the United States (1890), the social statistics of cities (1891), the vital statistics of the District of Columbia and Baltimore (1893), New York and Brooklyn (1894), Boston and Philadelphia (1895), and the special statistics of the insane, feeble-minded, deaf, dumb, and blind (1895). To the Twelfth Census he contributed an analysis of its vital statistics (1904). To the theory of vital and medical statistics he made three separate contributions, viz., a series of papers published in the *Sanitary Engineer* (1883-'5), his Cartwright Lectures, delivered before the College of Physicians of New York in 1889, and a memoir published as part of the prolegomena to Sir Clifford Allbutt's *System of Medicine* (1896). In all these his familiarity with the mathematical methods employed by Farr, Rumsey, Körösi and the other writers before Karl Pearson is evidenced, and the conclusion of his Cartwright Lectures shows that he understood the fallacies and inadequacies of the older methods and saw clearly the need of the "correlations" subsequently employed by Pearson.

In his presidential address before the Seventeenth International Congress of Medicine at London (August 6, 1913), Sir Thomas Barlow, in naming the eminent physicians who had been prominent at the London Congress of 1881, referred to Billings as "prince of medical bibliographers." In this field Billings with his colleague Fletcher were, indeed, the successors of Haller, who catalogued the literature of anatomy, surgery, internal medicine, and botany up to the last quarter of the eighteenth century, and Callisen, who indexed the entire medical literature of the last half of the eighteenth century and the first third of the nineteenth. Billings's achievement in

this matter is a wonderful lesson in the utilization of opportunities as they come and was the fulfillment of a dream of his youth. In his reminiscences of his old medical alma mater, read in 1888, he has described his almost futile attempts to obtain complete statistics of operations for his graduating dissertation on epilepsy from the then medical libraries of the country (1861), and his realization of the fact that, while there was not a library in the world containing all the literature of medicine, there was not even a fairly good collection of such literature in the United States, so that exhaustive research in this field would require a visit to several libraries in Europe. "It was this experience," he says, "which led me, when a favorable opportunity offered at the close of the war, to try to establish for the use of American physicians a fairly complete medical library, and in connection with this to prepare a comprehensive catalogue and index which should spare medical teachers and writers the drudgery of consulting ten thousand or more different indexes or of turning over the leaves of as many volumes to find the dozen or so references of which they might be in search."*

Prior to 1836, there existed in the Surgeon-General's Office at Washington a small departmental outfit of medical books which had been gathered for the official use of Surgeon-General Joseph Lovell (appointed 1818). When Billings was assigned to duty in this office on December 31, 1864, the collection, which had been increased at intervals by Surgeon-General William A. Hammond and his successors, amounted to some 1,365 volumes. To Billings was assigned, among other things, nominal, if not official, care of this collection. Small printed catalogues of this tiny medical library had been issued from time to time, that of October 23, 1865, showing 2,253 volumes. At the close of the Civil War there existed a considerable "slush fund" turned in from the army hospitals and derived "from the sale of bones, fat, stale bread, slops, flour barrels, straw, manure, waste paper, old newspapers, etc., and from the tax on the sutler."¹ This slush fund, amounting to

* Cincinnati Lancet-Clinic, 1888, n. s., xx, 297.

¹ Med. & Surg. Hist. War of Rebellion, Washington, 1888, Med. Vol. iii, 959.

about \$80,000, Billings was permitted to use for the purchase of books for the Surgeon-General's Library, the subsequent catalogues of which made a showing of 6,066 volumes in 1868 and 13,330 volumes in 1871. In 1873, Billings issued a three-volume author catalogue, with some subject entries, showing a quota of about 25,000 volumes and 15,000 individual pamphlets. In 1876, he utilized his studies in nosology in the publication of a "Specimen Fasciculus of a Catalogue of the National Medical Library under the direction of the Surgeon-General, United States Army," consisting of a specimen index of authors and subjects arranged in dictionary order in a single alphabet, which was submitted to the medical profession for criticisms and suggestions. At this time, the library contained some 40,000 volumes and about the same number of pamphlets. The Specimen Fasciculus was regarded with great interest and favor by the profession, and received enthusiastic commendation from Dr. Oliver Wendell Holmes in his dedicatory address at the opening of the Boston Medical Library on December 3, 1878. Meanwhile Billings had acquired the necessary appropriation from Congress for increasing and completing his collections and on September 1, 1876, gained the valuable assistance of Dr. Robert Fletcher, of Bristol, England, an army surgeon of the Civil War, who was to be his faithful coadjutor in this work for the next twenty years and his successor for seventeen years afterward. In 1880, he at length obtained the necessary Congressional appropriation for printing a complete Index Catalogue of the library, and the first volume of this publication, a stout quarto of 888 pages, covering the literature by authors and subjects from A to Berlinski, was issued in the same year. Similar volumes of the same dimensions were issued annually up to the completion of the first series in 1895, when Dr. Billings was retired from active service in the army. The second series (volumes I-XVII) was carried on by Dr. Fletcher up to the day of his death (November 8, 1912), and is now complete in 21 volumes (1916), the two series comprising 37 volumes. In this publication, the entire literature of medicine and its collateral subjects from the earliest times down to the year 1916 is indexed in alphabetical order by authors and subjects, the latter indicated by appropriate

rubrics in bold-faced type, with abundant cross references. When we realize that most of the important literature of nineteenth and twentieth century medicine is buried in the files of medical periodicals, the magnitude and importance of the task of indexing it *seriatim* is plain. Of this work Billings was not only the organizer and promoter, but for thirty years he selected and bought the literature from publishers' and antiquarian catalogues, checked for indexing all the periodicals as they came in, devised the system of subject classifications and cross references and read the final revises of the proofs, to the galley sheets of which Dr. Fletcher gave his rare scholarship and critical acumen. In the earlier days, bound periodicals by the vanload were left daily at Billings's residence for checking, the work sometimes occupying him until the small hours of the night. The day was spent in administrative duties and in training the clerical force (most of them old hospital stewards) in the details of indexing, preparing copy and other library work. After Dr. Billings's retirement the classification, redaction and proof-reading of the second series of the Index Catalogue was superintended by Dr. Fletcher up to the time of his death (1896-1912). The Index Catalogue was an unusual thing to come out of a new country, but its enormous value to the medical profession and to librarians was soon recognized all over the world. The copies on hand in the larger medical libraries have frequently to be rebound on account of constant handling and Sir William Osler has related how worn and much bethumbed are the copies in European libraries. As a monthly supplement to the Index Catalogue, the Index Medicus, an extra-official publication giving a classified record of the current medical literature of the world, month by month, was begun by Dr. Billings and Dr. Fletcher in 1879, the redaction of this publication being principally in the hands of Dr. Fletcher. The annual index of the twelve monthly numbers comprises a complete conspectus of the author entries in alphabetical order and a minutely subdivided subject index which is, in respect of classification, a sort of annual Index Catalogue *en miniature*. The first series of the journal ran through 21 volumes (1879-99), when it died out from lack of financial support. In 1903 the Index Medicus

was revived under the financial patronage of the Carnegie Institution of Washington, with Dr. Fletcher as editor-in-chief (1903-1911) and is still current.

In building up his unique collections which, under Col. Champe C. McCulloch's administration, now number 226,128 volumes, 337,110 pamphlets, and 5,249 portraits of physicians, Billings did not rest content with Congressional appropriations, but in his restless indefatigable way aimed to complete his periodical files and fill up lacunæ as far as possible by a resolute *faire flèche de tout bois*. To this end, he kept on hand large quantities of duplicates, which he personally fostered for exchange purposes, sent out endless trains of letters to secure public documents and accessions by gift, where possible, and ransacked all private collections which were thrown open to him for rare items. Dr. Holmes has humorously described how Billings entered his private library at Cambridge and immediately swooped down upon the most valuable things on his shelves. "Why, sir," he said, "Dr. Billings is a bibliophile of such eminence that I regard him as a positive danger to the owner of a library if he is ever let loose in it alone." In still hunts of this kind, his right-hand man was the late Thomas Windsor, an ophthalmic surgeon, of Manchester, England, who died in 1910, leaving the most valuable items in his collection to the Surgeon-General's Library. Windsor was an eccentric, who, like Landor, would give away any book about him if it suited his whim, but would stickle to the last farthing in the adjustment of his accounts with a public institution. Eccentric were the provisions of his will, which stipulated that his executors should spend as little as possible on his funeral, invite no one to it, and insert no notice of his death in the newspapers, while some £20,000 of his estate were to be used for the relief of suffering in any way, provided that nothing should be given to any hospital, dispensary, medical society or institution, nor to any church or any charity subject to a religious body or sect. Yet he was a bibliophile of rarest talents and enthusiasm. From his country seat, "The Polygon" (Ardwick), letter after letter went out in quest of rare items for the Surgeon-General's Library, the historical collections of which he did much to complete, early and late. He had a kind

of supernatural *flair* for locating rare items in antiquarian book shops. When in Washington he would smilingly extract such things from the shelves of the local establishments like rabbits from a conjurer's hat.

Through his lectures and writings on the history of medicine, Billings was one of the original prime movers in the development of its study and investigation in the United States. From the date of the earliest contribution to the subject made in this country, the "Medical Discourse" of Dr. Peter Middleton (New York, 1769), little had been done until Dr. Oliver Wendell Holmes, in 1842, began to write those brilliant, witty, and learned papers which eventually made up his "Medical Essays" (1883), the most important American work dealing with medical history in its day. In 1876, Billings published his centennial survey of American medical literature (noticed below), which was just and critical even to the point of *nil admirari*. In 1881, he was asked to deliver one of the general addresses at the International Medical Congress, choosing as his subject "Our Medical Literature," a genial, if critical, examination of the world's medical literature at the time. This discourse, replete with wit and wisdom, made a deep impression, is still remembered and read and ranks with the earlier essays of Holmes and Toner, Weir Mitchell's history of instrumental precision in medicine and the later studies of Osler, Welch, Jacobi, Fletcher, and Kelly, as among the few contributions of permanent value made to the subject of medical history in this country. Worthy of especial mention are Billings's history of medical libraries in the United States (1876), his addresses on "Medical Bibliography" (1883) and on "Methods of Research in Medical Literature" (1887), which, in connection with his model bibliographies of cholera (1875) and alcoholism (1894), became, as it were, texts and reference manuals among the medical librarians; his "National Medical Dictionary" (1885), a collaborative work giving all the medical *termini technici* in English, French, German, and Italian; his alumni address on "The Medical College of Ohio Before the War" (1888); his bantering consideration of "American Inventions and Discoveries in Medicine, Surgery, and Practical Sanitation," read at the bicentennial of the American patent

system (1891); his contribution to the history of the Smithsonian Institution (1897); his survey of the "Progress of Medicine in the Nineteenth Century" (1900); and his "History of Surgery" (1895), which still remains the best work on the subject in English. In 1877-8 and some years after, Billings gave a regular course of lectures on the history of medicine at the Johns Hopkins University. Another course was delivered at the Lowell Institute in 1888. These were never published, with the exception of the introductory Lowell lecture on medical folklore, which is highly original. He was one of the founders of the Charaka Club in New York City (1898), and in 1906 read before it a suggestive paper on "The King's Touch for Scrofula."

In the advancement of medical education and in the improvement of the general condition of medicine in this country, Billings played a leading part for at least thirty years. The secret of his influence lay partly in his character, which was forceful, aggressive, firm, self-reliant, but mainly in the quality of his mind, his cool detachment, his wonderful sagacity and insight. In this relation, he early made his mark in his absolutely straightforward advice and suggestions to the Johns Hopkins Hospital trustees in regard to the best needs of the future medical school. These were delivered in a way which proved absolutely convincing through their blunt honesty and transparent sincerity, as of a man laboring under no illusions. Thus Billings soon gained the highest reputation, at home and abroad, for that rare virtue, unfailing reliability of character and judgment. His lectures on medical education (1878) and his "Condensed Statement" of the requirements of the principal European universities for graduation in medicine (1893) were, with a letter sent by the late Sir Henry Acland to the hospital trustees in 1879, of greatest value to the Johns Hopkins University and other American institutions. Through his later life he continued to stimulate interest in the subject through various wise discourses, such as those on "Ideals of Medical Education" (Yale, 1891), on "Hygiene in University Education" (Oxford, 1894), his address to the graduating class of Bellevue Hospital Medical College (1882), which is a delightful burlesque of the platitudes usually delivered by the

vaedictorian and the tender of diplomas, and his speech before the Harvard Medical Alumni Association (1894). On the general advance of medicine in the country the influence of his critical, humorous, sagacious spirit was no less remarkable. In 1876, Billings published, in the volume *A Century of American Medicine*, a centennial survey of the medical literature and institutions of the United States which, in its extremely critical tendency, marked a great advance upon the laudatory and lapidary expressions of our earlier writers upon this theme. In this regard, the very titles of some of our earlier (and happily short-lived) medical periodicals—*The Granite State Medical Revolutionist and Hygienic Advertiser*, *The Georgia Blister and Critic*, *The St. Louis Probe*, *The Indiana Scalpel*, *The Drug Mill*, *The Medical Waif*, *The Quarterly Review of Narcotic Inebriety*, *The Dental Jaiirus*—speak for themselves. The writers of the time, in the expressive words of Holmes, “chewed the juice out of all the superlatives in the language in Fourth of July orations,” and this florid, stilted, uncritical spirit was not confined to the vulgar, indeed attained its apogee among the learned in the otherwise admirable discourse on “Silver Sutures in Surgery” (1857), by Marion Sims, the founder of modern operative gynæcology. Billings was at no time inclined to wear “the foolish face of praise.” His strictures upon the status of our medical literature, just but kindly meant, gave considerable offense in certain quarters. But nothing was more needed at the time and this critique, with its dignified message of hope at the end, established certain norms of excellence which have made for good work ever since.

The address which Billings delivered at the International Medical Congress in 1881 was reprinted and translated in most of the medical journals and made him known all over Europe. His work on the Johns Hopkins Hospital, on the Index Catalogue, on the U. S. Census and his many publications brought him all the more in the public eye in this country and made him in every sense of the word a leader of the medical profession. In 1886, he was asked to represent the United States by delivering the annual address in medicine at the meeting of the British Medical Association at Brighton, England. In this address, he reviews the deficiencies in our medical organization

in a cheerfully critical way, showing that even in 1883 there were "90,410 persons calling themselves physicians" in the United States and Canada, or one to every 589 persons in the United States, and that the proportion of these is generally lowest at the South and in the Southwest. In explanation of this fact, he produced shaded maps showing that it was in just these regions that malarial and yellow fevers were most prevalent, advanced the general theorem that "malaria and science are antagonistic," and insisted that neither "penal nor restrictive legislation" could induce highly educated physicians to settle in such localities. While all this was meant as a joke, since Billings himself admits that "it was within the limits of this malarial shadow that the foundation of modern gynæcology was laid by Marion Sims, of abdominal surgery by McDowell, Battey, and Gross, of an important part of the physiology of the nervous system by Campbell," nevertheless the bantering was misinterpreted as an expression of sectional prejudice by Southern medical editors, particularly in connection with the curious affair of the approaching International Medical Congress at Washington in 1887, in which Billings and the other committeemen, appointed at Copenhagen in 1884, were unjustly thrown out of their original positions by the American Medical Association at the New Orleans meeting, May 8, 1884. Discussion of this imbroglio has no place here; but inasmuch as the trait of baiting the South had become the fashion among our superficial people during the Reconstruction period and after, the natural attitude of the Southerner himself towards the old South being touchy and sentimental, like that of the Catholic nobles toward Mary Stuart—

"The Queen of Scots lived gently in repute,
She has much wrong,"

Billings's address was regarded by some as a tactical blunder. His strictures really stimulated the South to better efforts; his apparently hopeless view of its case in science was intended as a spur and an incentive; and, at the conclusion of his address at the opening of the new Army Medical Museum in 1887, he urged that "the museum specimens, coming as they do from the sick and wounded of both armies, and contributed by both

Union and Confederate surgeons, enforce the lesson of the unity of the profession and of its interests, as well as that of our country." As a matter of fact, the ancient Athenian civilization was developed in the same parallel of latitude (38° N.) as the once malarial Washington, and, although many writers assert that the downfall of Greece and Rome was due to the introduction of malarial fever, yet the splendid work of the Indian Medical Service in the peninsula of Hindustan, or of such southern Americans as Walter Reed and Gorgas in Cuba and Panama, shows that preventive medicine is fast overcoming the restrictions of climate and of tropical diseases upon scientific productivity. In 1900, Billings spoke feelingly of the work of Walter Reed, who, during the last week of his life, became one of his successors as librarian of the Surgeon-General's Office.

On June 1, 1896, Billings resigned his professorship of hygiene in the University of Pennsylvania to become director of the New York Public Library, in connection with the proposed consolidation of the Astor, Lenox and Tilden foundations. Here his unique administrative abilities were to find widest scope. In the complex legal and political details of selecting and securing a proper site for the proposed new building and the proper appropriations for its maintenance, he played an important part, and the original plan of the structure, which was but little modified in the end, was sketched out with his own hand at Atlantic City on April 5, 1897, and exists in two states and a facsimile reproduction.⁸

"In essence the plans there set down are those of the building as it stands today, the stack at the rear, main reading room on top, other rooms and offices grouped around the two courts. From the issue of preliminary notice to the competitors until the building was finished and opened fourteen years later the hand of Dr. Billings followed closely every development of plan on the architect's drawing board and every translation of it into the brick and mortar, iron and wood of the workman. To him more than to any other individual must be given credit for the plan and arrangement of the present building, this in no way detracting from the credit due to Messrs. Carrère and Hastings for their able services as architects."⁹

⁸ For which see *Library Journ.*, N. Y., 1911, xxxvi, 238.

⁹ H. M. Lydenberg, *Bull. New York Pub. Library*, 1913, xvii, 310.

At the laying of the corner-stone, November 11, 1902, Mr. John Bigelow, President of the Board of Trustees, said: "I should fail of my duty if I did not here, on behalf of the Board of Trustees, publicly recognize our incalculable obligations to Dr. J. S. Billings, who seems to have been providentially sent to conduct the executive affairs of the new corporation." On May 23, 1911, the new building, one of the finest and best appointed of modern public libraries, was formally opened to the public. As Mr. Edwin H. Anderson, the present Director of the New York Public Library, has said, Dr. Billings was "in a very real sense its creator." Of the gigantic administrative achievement which is to be credited to Billings during the seventeen years of his directorate of this library, there is no better account than that given by its Reference Librarian, Mr. H. M. Lydenberg:

"In those days both the Astor and the Lenox buildings closed at three or four o'clock in winter and at five or six during the rest of the year; each closed for three entire weeks in the summer. The combined staff numbered but forty people. Neither library had a complete general catalogue or a shelf list. The new library had no provision for home use of books, this work being carried on by some dozen independent agencies.

"Acting on the recommendation of Doctor Billings when he took active charge of the work in the summer of 1896, the trustees enlarged the staff, put electric light in both buildings, extended the hours of closing to six o'clock throughout the year.

"The combined collections contained about 350,000 volumes, classified by fixed location and incompletely catalogued. A system of relative classification was devised by Doctor Billings and under his direction applied to the entire collection. A uniform system of cataloguing was adopted for both buildings; for each a public catalogue was provided in dictionary form on standard size cards. With these catalogues were combined as rapidly as possible the catalogues previously existing, some of which were printed in book form, some in manuscript on standard cards, some in manuscript on large cards and some on small cards.

"As executive officer of the trustees he arranged a system of co-operation with the other large libraries of the city, a limitation of the field of each, a prevention of useless duplication of effort. With the place of The New York Public Library thus defined he threw his extensive experience in the book trade, his widespread and minute knowledge of books and his boundless physical and mental energy into the work of extending and completing the collections of the library. Subscriptions to current periodicals were doubled and trebled, the con-

tents of the important magazines were represented in the public catalogue by index cards, a co-operative indexing of the less popular magazines was begun in connection with four or five other large reference libraries.

"The activities of the library were enlarged in many ways. Departments of maps, music, manuscripts, and prints were established and put on firm basis. A system of staff meetings were begun for informal discussion of questions of policy and administration, for improving the acquaintance of the members of the staff, for increasing the loyalty and solidarity. A monthly 'Bulletin' was started as a medium of information about the work of the institution, its growth and progress, the help it offered students and scholars.

"The first five years of his life with The New York Public Library saw the staff well organized, the usefulness of the institution increased many fold, its collections more than doubled, their use intensified, new life and energy in every member of the staff.

"His next achievement was the consolidation of the New York Free Circulating Library with its eleven branches, the establishment of the circulation department, the securing of the gift of \$5,200,000 from Mr. Carnegie for circulation branches, and the union of practically all the circulating systems in the city."²²

In his work of upbuilding The New York Public Library, Billings was materially assisted by the sagacious counsel of his friend Mr. John L. Cadwalader, late president of its board of trustees, and by the loyal support of his co-workers in the institution. The report of the library for 1916 shows that it now contains 2,459,996 books and pamphlets; that it has, besides its monumental central building, 43 branch libraries (37 of which were erected from funds supplied by Mr. Carnegie), 32 in the Borough of Manhattan, 7 in the Bronx, and 4 in Richmond, and that the total number of its employees has increased from 732 in 1910 to 1,224 in 1916. In his selection of Mr. Anderson, as his successor in this library, Billings showed as everywhere his keen surety of judgment in estimating the moral and administrative capacities of men.

Dr. Billings was one of the original incorporators of the Carnegie Institution of Washington (January 4, 1902), vice-chairman of its Board of Trustees up to December, 1903, after which he was chairman until his death and a member of the executive committee. He missed only one meeting of the Board

²² *Ibid.*, 309-310.

of Trustees and attended all but thirteen out of ninety-nine meetings of the executive committee (1902-13). During this period, Dr. Billings secured the revival of the *Index Medicus*, with Dr. Fletcher as editor-in-chief (1903), was a strong supporter of the Nutrition Laboratory (erected in Boston, 1907-8), the Solar Observatory (erected 1905-6), the Department of Meridian Astrometry, the Department of Historical Research, the Department of Experimental Evolution and the *Index* to State Documents. In his advisory relation to the institution he had, as President Woodward has testified, the necessary sense of humor and proportion, the breadth of learning, the high courage and fearless detachment of mind which availed to make his services of incalculable value to the institution during its formative and experimental period. The early experiences of his rugged and self-denying youth had made him perhaps a little too considerate of the "sincere but deluded enthusiasts," the self-appointed genii from "the long grass and the tall timber," who pester and bullyrag the institution with their importunities and "inventions," but, in the main, he sat securely in his judgments, and he was loyal and consistent in his conviction that the benefits conferred by the scientific grants of the Institution should never be of the eleemosynary kind.

In acknowledgment of the value of his work in science, Dr. Billings received honorary degrees from the universities of Edinburgh (LL. D., 1884), Harvard (LL. D., 1886), Oxford (D. C. L., 1889), Munich (M. D., 1889), Dublin (M. D., 1892), Budapest (M. D., 1896), Yale (LL. D., 1901), the Johns Hopkins (LL. D., 1902), and was an active or honorary member in many medical and scientific societies. On April 17, 1883, he was elected to membership in the National Academy of Sciences. His name was proposed and his election passed upon mainly on the strength of his work in upbuilding the Surgeon-General's Library and its Index Catalogue, which Sir William Osler has pronounced his "float down to posterity," which Professor Welch has defined as the most important contribution to American medicine (as distinguished from laboratory and clinical contributions to the different branches of medical science) in the nineteenth century, and which Professor Adami, of Canada, has declared to be the outstanding produc-

tion of American medicine in the eyes of Europe. He was treasurer of the Academy from 1887 until 1898, a member of the council (1896-1907), of various committees, such as that on publications (1888-'99), and one of the trustees of the Barnard Medal Fund, (1900-1908). During the last years of his life (1906-1912), he was active on various committees for enlarging the scope of membership to include anthropologists, psychologists, philologists, etc. In 1885, he presented (with Washington Matthews) memoirs on composite photographs of skulls; in 1894-'5 the researches made by his pupils in the Laboratory of Hygiene, and contributed biographical memoirs of Joseph Janvier Woodward (1885), Spencer F. Baird (1889), and Francis A. Walker (1902).

In public and military hygiene, in hospital construction and sanitary engineering, in the mathematical methods of vital and medical statistics, Billings was an actual and accomplished worker in applied science, using the term in the restricted sense of man's attempt to understand natural and physical phenomena in order to predict and control their consequences. In relation to the loose aggregation of sciences which goes under the name of medicine, he was essentially the masterful pioneer, organizer, and administrator, and no fair-minded and discriminating historian of medicine in the future can fail to recognize him as the man of his generation who did most to advance the cause of higher medical education and of the general literary status of scientific medicine in this country. Withal he was a man of singular versatility, widely read in all branches of secular and scientific literature, particularly in such subjects as the minute fungi and the mystic and theosophic lore of the far East. His quaint sympathy with self-deluded "inventors" may perhaps have been due to the fact that he was an inventor of no mean capacity himself. In 1870, he devised a ventilating double-fireplace for army barracks; in 1881, he suggested the possibility of obtaining telegrams and phonograms from the heart, which was brilliantly realized by Waller, Einthoven, and others during 1889-1903; in 1884-'5, he devised (with Major Washington Matthews) a method of taking composite photographs of skulls; in 1880 he suggested the general plan for the Hollerith electrical counting and integrating machines, which

are now used by the United States Census; he devised some of the tabulating methods employed in vital, medical, and military-medical statistics, and he originated the methods of bibliographic technique employed in the Surgeon-General's Library and the New York Public Library. As an organizer and administrator, he carried every one along with him by the force of his Viking personality, but to his personal friends and to his co-workers, whom he bound as with "hooks of steel" to himself, he was a good example of the poet's "great individual, fluid as nature, chaste, affectionate, compassionate, fully arm'd." All along the line he upheld the honorable Saxon belief that the game of life must be played according to its ethical rules; but certain traits of aggression which produced the superficial impression of hardness were known to his intimates to be due to the effects of internal disease, to the fact that "calculus racked him," and that he was a life-long sufferer from the cancerous diathesis. He was eight times on the surgeon's table—four times for major operations—but, as in the case of a fracture of the ribs occasioned by the jolting of a railroad car, he treated all this lightly and tried to conceal it from his wife and family. In this he showed the *Tragemot*, the superb courage in endurance, of his Scandinavian ancestors. His friend, the late Sir Lauder Brunton, said:

"As his name shows, he was of Scandinavian ancestry, and he retained the overpowering strength and energy by which his Berserker forefathers carried everything before them. But he concealed them under such a quiet, unassuming, courtly exterior that those who had only a casual acquaintance with him could hardly suspect the enormous latent energy he possessed. Though his learning was stupendous, he never obtruded it, but along with an easy flow of language and a quiet vein of humor it made him an excellent speaker and an agreeable companion, while his strong nature, affectionate disposition, and kindly ways rendered him at the same time beloved and trusted by those whom he honored with his friendship."

To the discriminating, in England and America, Billings seemed, in personality, a great (in the sense of an absolutely reliable) man. Dr. Welch said: "He was the wisest man I ever knew." Colonel Walter D. McCaw (U. S. Army) said: "He undoubtedly had the making of a great soldier. He would

have made a great general. He would have made a most able prime minister, and he would have had his own way. He would undoubtedly have made a great ruler, probably an easier position to fill." Mr. J. Y. W. MacAlister, librarian of the Royal Society of Medicine, said: "He was a *great* man in every sense of the word, * * * and *we* are not likely to look upon his like again." Of his position among his medical colleagues, Dr. Jacobi, the Nestor of our American profession, wrote:

"He was not really 'one of us,' no practitioner, no consultant, not often seen in medical societies. I believe there are many of the younger men who never saw him. But all knew him, knew he was above us. His superior position was recognized by every one. Everybody knew he had rendered and was constantly rendering services unique and such as nobody else could render or imitate."

And again, in the spirit of the inscription over the French Pantheon, "*Aux grands hommes la patrie reconnaissante*," Jacobi said:

"We trust that it is not probable that the light-heartedness and forgetfulness of an ungrateful republic will deal with his memory as with that of lesser men. It is by him that the combination of American idealism and creative constructiveness is best represented, an example to be emulated by all men, both great and small, in all countries. * * * His life itself, ever vigorous, ever modest, ever bountiful, is his eulogy."



Wm. Stimpson

NATIONAL ACADEMY OF SCIENCES
OF THE UNITED STATES OF AMERICA

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BIOGRAPHICAL MEMOIR

OF

BENJAMIN OSGOOD PEIRCE

1854-1914

BY

EDWIN H. HALL

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Our colleague, Benjamin Osgood Peirce, who died in Cambridge on the 14th of January, 1914, was born in Beverly, Massachusetts, February 11, 1854. Of his ancestors, Richard Norman came to Gloucester in 1623, John Peirce to Watertown in 1637, John and Christopher Osgood to other parts of eastern Massachusetts before 1640. John Peirce had a son Robert, but after the Cromwellian era first names taken from the Old Testament prevail in the family, and it is hard to refrain from using the robust terms of the Old Testament genealogies in reciting the generations that follow. The son of Robert was Benjamin, and the son of Benjamin was Jerathmiel, and the son of Jerathmiel was Benjamin 2d, who fell at Lexington, and his son was Benjamin 3d, whose son was Benjamin Osgood 1st, the father of our friend.

From Jerathmiel were descended also Jerathmiel 2d, and his son Benjamin, Librarian of Harvard College from 1826 to 1831, and his son Benjamin, Tutor or Professor of Mathematics at Harvard from 1831 to 1880, among whose sons were James Mills, also for many years Professor of Mathematics at Harvard, and Charles Sanders, a brilliant mathematician and projector of the philosophic cult of Pragmatism. Without a break, save perhaps for a few months in 1831, some one of the descendants of Jerathmiel Peirce was in the service of Harvard College from 1826 to 1914. Three of his descendants have been members of the National Academy. In the annals of intellectual achievement in America there is no greater name than Peirce.

Perhaps, too, the name Jerathmiel had a certain potency. It sounds like a whole thunder-peal, the threatening rumble, the climactic crash, the soft and reassuring diminuendo. This name is derived or recreated from the lifeless Jerahmeel of the Old Testament Chronicles by the simple but miraculous

change of inserting a *t* and putting an *i* for an *e*. I have wished to claim this transformation as a New England achievement, directly inspired, and have refrained from verifying a suggestion that the greater word merely conforms to the Hebrew pronunciation of the ancient name.

There were contrasts of fortune among the descendants of Jerathmiel Peirce. One of his sons, Jerathmiel 2d, became wealthy as a merchant and built the famous Peirce-Nichols mansion, which stands today as one of the architectural treasures of Salem. The other, a baker in business, killed in the Concord-Lexington fight of April 19, 1775, was followed by a posthumous son who fared ill at the hands of a stepfather, was bound out to a hard master, and so badly treated that he at last ran away to shift for himself.

But the boy came of a sturdy and generous breed. We may be sure that it was no ordinary man who, at the age of thirty-seven, far older¹ no doubt than the great majority of those in arms, hurried across the country from distant Salem to meet his death in that first clash of arms in the Revolution, the only citizen of his town to fall at the hands of the British on that day. So the runaway apprentice, sustained perhaps by pride in the heroic father whose face he had never seen, having at any rate the same blood in his veins, was soon able to make his own way, neither broken by misfortune nor embittered by injustice. At twenty-seven years of age he had built and owned a large house in Beverly, the house in which his son and his grandson, our colleague, and this colleague's first daughter, Jessie, were born. A little later he had mortgaged this house to promote the building of a Baptist meeting-house; for a Baptist he was, and the Baptist tradition remained in the family.

He married well. His wife, Rebecca Orne, a woman of great piety and dignity, counted among her New England an-

¹ Thus in the Danvers Company, which he may have accompanied, though not a member of it, the oldest man killed this day was 33, the ages of the others who fell ranging from 25 to 21. In fact, Peirce was probably too old to be naturally enrolled among the Minute Men. His name is not to be found in the official register of Massachusetts soldiers and sailors of the Revolutionary War. He seems to have been a *franc-tireur*.

cestors a considerable number of clergymen and magistrates, men of note and influence in their time and place. Of these was John Osgood, one of the founders of the first church in Andover, Mass., and the name Osgood, thus brought into the Peirce family, has continued in active use there in three generations. Our colleague, his father, his mother also, as it happens, and his two daughters have all borne it as a middle name. It is small wonder that in England, at the scientific meetings of 1912, the family came to be known as the Osgood-Peirces.

The first Benjamin Osgood Peirce, born in 1812, was in due course of time sent to the Baptist College at Waterville, Me., where he graduated in 1835. He married, in 1841, Miss Mehetable Osgood Seccomb, a native of Salem. She was a lady of excellent family connections and traditions, with one or two reputed witches, of the eminently respectable Salem variety, flitting somewhere in the background of her ancestry. Though born in adjoining towns, Mr. Peirce and Miss Seccomb met for the first time in Georgia, where both were engaged in teaching.

In the case of a man so remarkable as our late colleague it would be interesting, if it were practicable, to trace the influence of each line of inheritance for some generations back; but this is a task beyond the powers of the present writer, and perhaps no one could successfully undertake it. The impress of each parent was strong upon him. He resembled his mother in certain physical and moral aspects; but it seems probable that the father was the dominating influence in his mental inheritance and in his education. An examination of family photographs confirms verbal report in attributing to the mother dignity, force, and poise; to the father like qualities, in so far as they are compatible with great intellectual vivacity and variety of interests. A picture of the mother gives the impression that the photographer could take his time, that his subject would look just the same the next minute or the next hour; a picture of the father, like one of the son, suggests by a certain gleam of the eyes and a certain mock severity of the mouth that the present attitude of stillness is

maintained with effort and will vanish into something very different the instant restraint is removed.

After his marriage, in 1841, Mr. Peirce remained for several years in the South as Professor of Chemistry and Natural Philosophy at Mercer. Returning to Massachusetts in 1849, he engaged as a merchant in the South African trade; but evidently business did not wholly engross him. He remained a scholar, had much to do with the Public Library of Beverly, indulged in practical mechanics as an avocation, and took an active part in the early education of his son. Tradition in the family says that the two used to speak Latin in their walks together, and this seems altogether probable to those who knew our colleague's proficiency in that language.

In 1864 Mr. Peirce visited the Cape of Good Hope, going in a sailing vessel and taking with him his son, then about nine years old. This voyage is of interest to us because it gave the boy occasion to write a number of letters which have been preserved and which give more than one indication of the kind of man the writer was to be. They are wholesomely boyish, with an occasional slight error in grammar and a pleasing lack of consecutiveness in the narration of incidents and observations. For example: "It seems queer to see the rebel officers (of the raider *Alabama*) walking about. I am going to try to get another monkey to carry home. We have had wild game several times, but I don't like it very well," etc. But the writing gives promise at least of that fair round hand which is illustrated farther on in these pages, and the lively vigor of the narrative reminds us of the ceaseless activity of later years. He asks his sister not to let certain of his possessions get soiled, a most extraordinary request for a boy, but according well with his lifelong horror of dirt. More significant still, however, are the messages of affection sent to numerous friends at home. To the end of his life Peirce was actively, thoughtfully, friendly toward a host of people. He remembered everybody's birthday, inquired after everybody's health, and strove to contribute to everybody's happiness. He is said to have occupied himself at Cape Town with schemes for blowing up the *Alabama*; but I have no doubt he always

made provision for the safety of the crew. There was no hardness in his heart. He has told me that when, as a boy, he sometimes had to fight another boy, he always labored under a certain disadvantage in not being able to get mad enough to enjoy hurting his enemy.

He is said to have retained in his memory so accurate and detailed a picture of Cape Town as to astonish in 1912 a South African whom he met in England. Any one who knew Peirce can well believe this. He was always eager for all sorts of information, and he had the capacity to store it. He acquired it as naturally and assiduously as his father gathered shells, minerals, and coins. Moreover, like most people with extraordinary collections, he had a certain joy in displaying his accumulations.

He was venturesome enough on shipboard to excite the anxiety of his mother, as a normal boy with a normal mother should be. It is related that on one occasion in rough weather he was perched on a boom when it swung outboard. Perhaps a more significant incident was his quiet capture, under his arm, of a large rat which had attacked him in his cabin. For a boy of ten years this was no slight exploit. In general he had a liking for animals, and he was permitted to have a variety of animal pets, though he seems to have formed no favorable opinion of their moral and mental character. Two of his conclusions, based on knowledge, were: "There is no piety in a goat" and "Compared with a turtle, a hen is an intellectual animal."

We here for the first time catch a glimpse of that sportive disposition which was so powerful an element in his make-up. He loved fun, and he made fun, always without malice, all his life. He early developed an inveterate fondness for slang, a turn which shocked his parents, both irreproachable in speech as in other matters. I never heard him utter an "unprintable" word,² but he used habitually some expressions that looked queer in print. His parents, after laboring with him

² In fact, I think it probable that he adopted his grotesque, but always clean, habit of speech as a substitute for the profanity and general foulness of mouth that he must have been familiar with in some of his boy companions.

in a vain effort to correct his conversation, wisely concluded to let him have his own way, or, as he would have said, "to go his own hooter." Why *hooter*, I never knew.

A more serious perplexity—in fact, a real disappointment and grief—came to his parents when, at the age of sixteen, the boy seemed to lose his ambition for scholarship. There is more than one version or theory of this phenomenon. One is that he was wayward, perhaps through his intimacy with other boys less carefully reared; but it is difficult to think of him as rebellious at any time in his life. It seems more probable that, owing to rapid physical growth and development, he really experienced a temporary mental lassitude. Possibly, too, there was some question, some difference of wish in the family, as to the particular college he should attend, if he went to college at all. Whatever may have been the reason, the fact is that for about two years, from the age of sixteen to that of eighteen, he worked regularly as a carpenter's apprentice at or near his home, taking all the rough experiences that came in the way of this occupation. Probably this life was good for him at this time, though some of his relatives lamented him as a light that had failed. The sturdy labor thickened and toughened the muscles on his big frame, and the methods of a professional workman became a habit with him—that is, the best of these methods; but one injunction from his carpenter "boss," though he doubtless obeyed it while under orders, amused him much in later years. It was substantially as follows: Always keep up an appearance of having plenty to do; if there is nothing else, find a pile of boards and shift it over from one place to another.

I never heard Peirce express any regret for the manner in which he spent these two years. They were pleasant and profitable to him in various ways. Though no longer, it would seem, looking toward a college career, he kept up his Latin and his habit of general reading. He had inherited from his father, who played the flute beautifully, a fine appreciation of good music, and he had an excellent bass or baritone voice. Now he joined the Salem Oratorio Society and vastly enjoyed the singing there. A Beverly organist made him familiar with

the fugues of Bach. In short, he was unconsciously fitting himself to serve, as he did serve for many years, in the capacity of member of the Committee on Honors in Music at Harvard. Moreover, during this period of apprenticeship he "made a profession of religion" and became a member of the Baptist Church, to which his father and mother belonged.

In 1872 the boy, now eighteen years old, decided that he wanted to go to college, to Harvard College, and, as only a few months remained before the opening of the college year, he worked very hard to prepare for the admission examinations. These he passed, as a whole, though I believe he was, curiously enough, "conditioned" in some particular of elementary mathematics. He did not take a room in college, but lived with his family, which had moved to Cambridge in order to be with him, about half a mile away. Thence he ran a telegraph line to the room of two classmates and intimate friends, Le Favour and Pine, in one of the college halls. It is said that his health was somewhat impaired for a time by his too severe labor just before entering college, and it is not improbable that he established this telegraphic communication with his friends by way of diversion during this indisposition. Illness was usually for him an opportunity to do something which he had not found time for in health.

Mr. Pine, now an Episcopal clergyman in Providence, has a vivid recollection of Peirce in his college days. They used to take long summer tramps³ together with great enjoyment, in which the rollicking humor of the latter was no small element. Percival Lowell was their classmate; the now President Lowell was a year behind them. At one time Peirce, Pine, Le Favour, and the two Lowells were all together in a course of elective mathematics given by Benjamin Peirce, then at the height of his fame. It was a notable company. Mr. Pine disclaims any talent for mathematics, and says he took the course because his friends were in it; but Le Favour

³ One of these probably furnished the material of a "Theme," which was Peirce's contribution to a little book, *Children's Stories*, by 11 *Sophomores*, published by Roberts Brothers in 1874.

was the one classmate who for the whole four years of college outranked Peirce, and the career of the others I have mentioned is well known. It is interesting to hear Mr. Pine's observation that Peirce and Le Favour took criticism in docile fashion from their illustrious teacher, but that the Lowells always wanted to argue the point.

Professor John Trowbridge has said that Peirce was his first research student. It was certainly under the influence of Trowbridge that he did the work described in his first research paper, printed in the Proceedings of the American Academy and bearing the date February 9, 1875—that is, the middle of his junior year in college. It has the title, *On the Induction Spark Produced in Breaking a Galvanic Circuit Between the Poles of a Magnet*. It is about ten pages long and is compactly written. It is, all things considered, a remarkable paper. A year or two before the opening of Johns Hopkins University it showed a Harvard junior referring to the work of Becquerel, Rowland, Maxwell, and Thomson, using intelligently and effectively an electromagnet (operated by Grove cells, or, later, Bunsen cells), an induction coil arrangement evidently constructed by himself, a Thomson quadrant electrometer, a Thomson galvanometer in connection with the induction coil and a condenser (said to be of one Farad capacity, but probably the *micro* was accidentally omitted), and applying the integral calculus handily to his experimental problem. There was not, probably, in all America at that time another college junior capable of all this; and there are not many such today.

A few months later appeared the next paper, a very short one, bearing Peirce's name, now coupled with that of his classmate, Le Favour. This dealt with the change of magnetization produced in an electromagnet by the use of an armature under various conditions. Professor Trowbridge was interested in this problem at this time, and undoubtedly he set his two students to work at it. Apparently Rowland's epoch-making research on magnetic induction in closed rings of the magnetic metal, though published a year or two before, had not yet received general recognition, though Trowbridge was one of the

first in America to see its importance. It is an interesting fact that the research work which occupied Peirce in his very last years had to do with magnetization, and that it also grew out of an investigation proposed to him by Trowbridge.

The next three papers, which bear respectively the dates March 14, April 11, and October 10, 1877, are of much interest and significance to the student of Peirce's career. During the year 1876-77 he was laboratory assistant to Professor Trowbridge, and the paper of March 14 is doubtless an outcome of this experience. It is entitled *On a New Method of Comparing the Electromotive Forces of Two Batteries and Measuring Their Internal Resistance*. It shows us the competent technician and the vigorous, enterprising teacher. We see in it a presage of the vigorous, masterly course in electrical and magnetic measurements, "Physics 3," which he established at Harvard about ten years later and maintained to the end of his life.

The paper of April 11, 1877, bears the title *Note on the Determination of the Law of Propagation of Heat in the Interior of a Solid Body*, and that of October 10 is an extension and application of this note, describing some experimental work in which Le Favour had a part. We may well consider the two papers as one. This is the first of Peirce's writings in what may be called the large mathematical manner—the masterly and seemingly easy application of great principles to a problem of wide scope.

Peirce was, it is evident, a learned man when he went to Germany for further study in 1877, but his conversational use of German and French at that time was limited. In later years he used to tell of his first visit to the German household in which he was to be domiciled at Leipsic. The landlady and her daughter, after vain attempts to reach an understanding with him by way of any language at their command, suggested waiting for the arrival of the son of the family, a student in the University. When this young man appeared he tried Peirce in Latin. Now, if ever there went to Germany an American student of physics who could speak Latin, Peirce was that student; but the German pronunciation of this

language was unfamiliar to him; so again there was difficulty, and the other young man, losing patience, exclaimed, "Have you never been to school?" I have heard no sequel to this story, but I can imagine that this young German had many occasions within the next few months to repent of his rash interrogation; for, though Peirce was humble-minded in a way and habitually called himself an ignoramus, he had no mind to be called that by anybody else. In all probability, under a semblance of asking information from a respected authority, he made a practice of exposing the German's ignorance of various matters till he had brought him to a proper state of mind.

Peirce stayed in Leipsic two years, studying especially under the elder Wiedemann, and gained his Ph. D. there in 1879. The next year he was in the laboratory of Helmholtz in Berlin. He profited, of course, by his sojourn in Germany. He saw the German way of doing things; he began lifelong friendships with notable men among his fellow-students—with Karl Pearson, for example; he enjoyed, as he did in America, long vacation tramps in good company; he heard the kind of music he loved, oratorios and organ recitals, and he sang in a choral society, the Riedelsche Verein. Above all, he met in Leipsic a young Scotch lady, a student in the conservatory of music, Miss Isabella Landreth, who, in 1882, became his wife.

But in the form of intellectual impulse he owed but little, I believe, to Germany. He published but two papers as the visible product of his studies there, and neither of these gave room for the play of his best powers. The first, *Ueber die Emissionsspectra der Haloïdverbindungen des Quecksilber*, printed in the *Annalen der Physik und Chemie* for 1879, is purely descriptive, giving in two pages the results of some observations he had made with the assistance, in some form, of E. Wiedemann. It is notable only for the extreme compactness of the style, a quality Peirce's scientific papers always had, which is well exhibited by the first paragraph: "The emission spectra of the mercury-haloid compounds are most conveniently obtained by conducting the stream of an induction coil through a Geissler tube, in which a small quantity of the salt is placed, and then heating it. If the tube is cold, the air spec-

trum appears. If it is slowly warmed with a Bunsen burner, this vanishes and the ordinary mercury spectrum is seen. By further heating, a light-band, different for each salt, comes out." Brief as it is, this paper reports on four different salts, and it probably represents a good deal of laboratory work. It doubtless made a genuine contribution to scientific knowledge and gave the experimenter useful experience in a field of research new to him. It appears to have been a kind of try-out, preceding the long grind of the dissertation research.

The second paper, the Inaugural Dissertation, is also entirely, or almost entirely, descriptive, containing only a trace of theory and no mathematics beyond the simplest arithmetic. It is entitled *Ueber die Electromotorischen Kräfte von Gas-elementen*. It was, I cannot help thinking, a rather unhappy turn of fate that set Peirce, a born mathematician and lover of theorems, to spend a year or more of immense labor on gas batteries at a time when physical chemistry was floundering through a bog of experimentation, directed only, or rather misdirected, by the false proposition that the electromotive force of a battery should be calculable from the heat yielded by the chemical operations occurring in it. He tested more than four hundred cells, of six different kinds, taking exhaustive pains. His results did not agree with the supposed principle just mentioned, and he sorrowfully states this fact. A few years later Willard Gibbs and Helmholtz had disproved this general theorem; but at this time and in Wiedemann's laboratory it was, apparently, unquestioned. It seemed a direct deduction from the law of conservation of energy; it was supported by the opinion of Sir William Thomson; experiments in some cases had seemed to confirm it.

Peirce was not temperamentally the man to challenge on the strength of his own observations a proposition so well supported. He had no passion for originality, for dissent; he had rather a passion for conformity,⁶ provided it involved

⁶ Thus, in speaking with an Englishman he would be likely to substitute for the moment the English for the American pronunciation of certain words. But, on the other hand, being on moral grounds opposed to the use of alcoholic drinks, he passed through his German experience without adopting the habit of drinking beer; and, being by religion a sabbatarian, he refrained strictly from work on Sunday.

nothing that seemed to him a moral sacrifice. He absorbed with consummate ease the teachings of the great leaders of science, and, so long as he could believe these teachings, he had no desire to question them. He was much more likely to suppose his own vastly painstaking work to be somehow wrong than to suppose that Sir William Thomson had made an error in his reasoning.

I never heard him blame Wiedemann or any one else for the disappointing outcome of his research work; but he formed and retained for many years the conviction that physical chemistry was a most unpromising field to labor in.

Returning to America in 1880, Peirce became for one year a teacher of mathematics in the Boston Latin School. In 1881 he returned to Harvard as Instructor in Mathematics, a title which he held for three years. In 1884 he was made Assistant Professor of Mathematics and Physics, and in 1888, on the retirement of Professor Lovering, Hollis Professor of Mathematics and Natural Philosophy. I also went to Harvard as a teacher in 1881, and so I was witness to his whole subsequent career there.

Though he had left Harvard only a few years before, he was a stranger to many of the fellow-teachers with whom he now came into close relations, and it was interesting to see the impression he made on them. They saw in him from the start something big and powerful, something genial and inspiring, and he soon came to be called by his initials, B. O., as an affectionate nickname. Though a most zealous and conscientious teacher, he seemed to do his necessary work with the greatest ease and to have his mind free half the time for stimulating and assisting others, always kindly, with great care not to seem patronizing or meddlesome. He would throw out casually, and as if he were merely anticipating by a moment his friend's thought, some suggestion which might never have come into the mind of the other, but which, once given, would have influence for years to come. For example, I once, finding that the subject of Probability was not treated by any Harvard teacher, proposed to offer a half-course in this subject. "Yes," said Peirce instantly, "Probability and the Kinetic Theory of Gases." This was about thirty-five years

ago. I am still giving the elements of the Kinetic Theory, but have long since given over lecturing on Probability as such. It was, I fancy, in a somewhat similar way that he started Byerly to give the course on Trigonometric Series, famous now for a generation as Mathematics 10.

He had whimsical turns of speech, odd gestures and attitudes. Thus, he called his intimates Deacon, or Colonel, or Uncle habitually. When he said Deacon Peirce or your Uncle Peirce, he meant himself. A favorite simile with him was, like a *cat in a fit* (pronounced *catnafit*). Some of his expressions—for example, *howl of suppressed emotion*, *true inwardness of all outdoors*—were probably not of his own invention; but they struck his fancy and resounded there. Others, like *jasm*, meaning vigor and power, seemed to be original with him, though his intimates soon adopted them. When I was about to be married, I took Peirce with me to look at a house. It had a winding stairway, behind which was a rather dark and secluded corner. He peered into this and remarked, "Boss place to sweep your dirt." Only one who knew his horror of dirt and of all shiftlessness could appreciate the comic effect of his suggestion.

In his later years his hair was thin, and he made frequent references to his bald spot. One day he said, "I have wondered for a long time why I couldn't part my hair in the middle, but now I know. I got between a lantern and a screen the other day, and then I saw that I had an odd number of hairs."

When leaving the laboratory at night he would stop for a moment at my door, always with some characteristic word or gesture. Sometimes he would tell me he wished I were a better man or urge me to "try to be decent"; sometimes he would shake his fist at me with a most evil grimace and go away without a word.

All this is enough, perhaps, to explain why Byerly in a burst of enthusiastic appreciation one day exclaimed, "Peirce is a cuss. He knows more mathematics than anybody else in the Mathematical Department and more physics than anybody else in the Physical Department, and in addition to all that he is a cuss."

Nevertheless, he was essentially a shy, deeply reserved man. The "antic disposition" that he wore was partly the spontaneous product of his good fellowship and sense of fun; but it served often, like the pretended lameness of a partridge, as a measure of protection, to prevent a possible intrusion.

Peirce was married, as I have already said, in 1882, in Scotland, but on account of illness in her family his wife did not come to America till 1884. Then, partly, it may be, for economy, but partly, I have no doubt, for privacy, they took a house in Waverley, three or four miles distant from Cambridge. Here they lived for some years, and here their second daughter, Emily, was born.

Peirce was generous of his time and labor for others, but when he was working for himself he wanted to be entirely undisturbed. Perhaps the very quickness and intensity of his sympathies made this necessary. The Waverley house was small, and he put his study table in the front hall; for there were few callers in that remote habitation. There he worked, facing a windowless wall. In after years, when he lived in Cambridge, few, even among his intimate friends, were ever invited into his study.

Moreover, as I have said, he was shy, fearful of being conspicuous. As an active Baptist Church member, he had sometimes to "boss a prayer-meeting," but it was always a painful effort for him. In the discussions of the Harvard Faculty his voice was almost never heard. Even when he was lecturing to a small class, made up of students who regarded him with admiration and awe, he would speak rapidly, in a low tone, with an occasional slight gasp suggestive of mental or physical distress. It was, perhaps, as a kind of relief from nervous tension that he would vary the ordinary precise speech of his lecture by occasional humorous twists, while maintaining a facial expression of unbroken gravity. Thus he frequently said *down stairs* for *in the denominator*, and if he had occasion to illustrate viscosity, for example, he might, instead of referring to Lord Kelvin's famous experiments with shoemaker's wax, mention *Mr. Geddes his bucket of glue*, Mr. Geddes being one of the laboratory janitors, better known as *Willum*.

In various other ways he showed this curious combination, a Gothic combination it may be called, of great sensibility with a love of the grotesque. He was so much affected by music that he sometimes dared not attend symphony concerts lest he should be made sleepless for the night. He once wrote home from Germany, "I have been listening to some chorales, Messiah, and passion music, played by ———, until my back almost crawled out of my skin. The laws of heat conduction will not account for the 'cold streaks' that run up and down a fellow's back when he is listening to some pieces of church music." He played music of this kind on the piano in the privacy of his own family. He sang well and gladly, we are told, in various choral companies. But the only songs I remember him as singing were "*The Little Brown Jug*" and a most absurd ditty, *Woollomooloo*, heard in a London music hall, where, suppressing for the moment his objection to such places, he had gone to hear Harry Lauder. He would beat out a tune with his forefinger on his cheek, varying the pitch by opening his mouth more or less widely, or, seizing the tail of the family dog and turning it as the hand of a hurdy-gurdy, he would grind out wild airs, singing through his nose.

His capacity for serious reading was immense. A volume of the Encyclopedia Britannica was to him like a novel to another man—a book to be read through with eager pleasure. Yet there was room in his mind for trifles and mere oddities of information. I remember hearing one of his intimate friends, Mr. H. N. Wheeler, express something akin to exasperation that Peirce should know the number of nails in a horseshoe. It seemed to him almost unbecoming that such a mind should occupy itself with such a bit of lumber. But it was probably easier for Peirce to know this thing than not to know it. It is likely that a distinct effort of self-repression would have been needed to prevent him from knowing the number of nails in a horseshoe. Yet he had a habit, a very obvious habit, of professing ignorance and asking for enlightenment. Now the desire for enlightenment was genuine. He really did want to know anything new one could tell him, and his "Thank you; I have learned something," was never sarcastic, though it often might have seemed so. But his professions of ignorance were

a kind of game. If he had really felt himself to be as ignorant as he often declared himself to be, he would have resigned his professorship. There were at least two motives that moved him to talk in this way; first, caution, lest he should be led into some trap; and, next, an amiable, though sometimes ineffectual, desire to encourage and draw out his interlocutor. It is probable that he got into this habit of self-depreciation when he was a boy, and felt apologetic toward other boys for knowing so much more than they did. If he found that either party to the conversation was likely to suffer from his pretense of ignorance, he dropped it immediately. No one could be more generous than he in sharing his knowledge or his other possessions with any one in need.

Among his useful accomplishments, by which others profited, was his ability to use tools and machinery. He was a practical printer; he could handle lathes, large or small. He had, perhaps, no marvelous skill in any one of these particulars, and he had no vain ambition to surpass the professional craftsmen at their own work, but he was possessed of a general, all-around, ability to do things with his hands and to estimate the skill and labor of others. This enabled him always to establish sympathetic relations with good workmen of any vocation. There was at Gloucester, where he often went in the summer, a little shop where one or two men made excellent fish knives in an old-fashioned way. To help trade, Peirce once gave them an order, to which they responded by making for him one of the most tremendous "weepuns" ever seen off a pirate ship, shaping the handle out of a treasured piece of teak from a famous vessel, the *Hotspur*. This knife, though too big for any domestic use, delighted Peirce, for he liked big things. He had, indeed, always a manner, a habit, of copiousness. In his household he bought sugar by the barrel; for his laboratory wooden furnishings he used, while they could still be found in the market, planks, not boards, of clear white pine; he made out problems years ahead for his courses; the plate of iron on which he made the study of heat-flow already described was about three feet wide and five feet long. He laid in long ago so large a stock of a certain kind of wire, made in Germany, that nearly four years after his death a manufac-

turer of apparatus was negotiating with the Jefferson Physical Laboratory for a supply, which he could not get elsewhere.

For some years after his return to Harvard in 1881 Peirce did but little original research. There were other things that seemed to him of more immediate importance. He wanted to get his own courses well established, to get other courses in mathematics or physics well started, and, after 1883-'84, to do his part in putting the work of the Jefferson Physical Laboratory on a solid basis. Through all his life he could neglect no labor that seemed to be his duty, and his sense of duty was far-reaching. There was, I think, little feeling of self-sacrifice in this. His passion was for being helpful, rather than for doing things men would call great. Many a man of far less ability, far less capacity for the broader undertakings of mathematics and physics, would have repined at the immense labor that he put into his laboratory course, Physics 3, a severe course of exact measurements in electricity and magnetism, an undertaking with no showy possibilities whatever. It was not, to be sure, the kind of course an ordinary man could have created and maintained. It was a rock of safety for some of the rest of us. It furnished us with standards, tangible and intangible; with examples of care and precision; with portable, loanable, not always returnable, constant cells and reliable resistance coils. Yet we understood well enough that we were not to go into the quarters of Physics 3 and take things away without his knowledge. He asked for and received at the start sole possession of certain rooms nobody else wanted. He filled these rooms with apparatus, much of it made with his own hands or by his particular direction, devoted exclusively to the uses of his course, except in so far as he might expressly give permission for its use elsewhere. He installed in charge of this apparatus a green chore boy, and trained him to great skill and usefulness; then let him go out to some wider career, and took another, to be treated in the same way.

It was in his willingness to do this kind of thing that Peirce showed his real humility, a humility dignified by moral force and ennobled by a spirit of devotion. It was all in keeping with, if not actually a part of, his religious life. If he had possessed one particle of that intellectual hauteur we some-

times can perceive in able men, he might well have been more widely known, but he would not have been so widely beloved. Who shall say that he did not choose wisely?

Not all of his teaching, however, was of this restricted and elementary character. He lectured for a time on thermodynamics, and afterward on the advanced theory⁷ of electricity and magnetism and on hydro-mechanics. His book on the Newtonian Potential Function, of which the first edition (143 pages) appeared in 1886 and the third (450 pages) in 1902, grew out of his coöperation with Byerly in Mathematics 10.

$$\begin{aligned} & \iiint h_u h_v h_w \frac{\partial}{\partial u} \left(\frac{\Omega}{h_u h_w} \right) dv = \iint \Omega \cos(u, n) dS \\ & h_u h_v h_w \left\{ \frac{\partial}{\partial u} \left(\frac{Q_u}{h_u h_w} \right) + \frac{\partial}{\partial v} \left(\frac{Q_v}{h_u h_w} \right) + \frac{\partial}{\partial w} \left(\frac{Q_w}{h_u h_v} \right) \right\} \\ & \iiint h_u h_v h_w \left\{ \frac{\partial}{\partial u} \left(\frac{\mu h_v \partial_v V}{h_u h_w} \right) + \frac{\partial}{\partial v} \left(\frac{\mu h_u \partial_u V}{h_u h_w} \right) + \frac{\partial}{\partial w} \left(\frac{\mu h_u h_v \partial_w V}{h_u h_v} \right) \right\} dv \\ & \partial_u^2 V h_u^2 + \partial_v^2 V h_v^2 + \partial_w^2 V h_w^2 + \partial_u \nabla \cdot \nabla(u) + \partial_v \nabla \cdot \nabla(v) + \partial_w \nabla \cdot \nabla(w) = -4\pi f \\ & \iiint \mu \{ \partial_u u \partial_v w + \partial_v u \partial_u w + \partial_u \mu \partial_v \mu \} dv \\ & \iiint \mu \cdot u \cdot \partial_u w \cdot dS - \iiint u \cdot \Omega(\mu w) dv \end{aligned}$$

Not many students were fitted to take the more advanced of his courses, but there were always a few eager to take anything he offered. That is all the following a teacher in the higher regions of mathematical physics can expect or even wish for.

In 1883 Peirce published in the *American Journal of Science* a paper of three pages *On the Sensitiveness of the Eye to Slight Differences of Color*, giving an account of an investigation suggested by Prof. Wolcott Gibbs. It is a character-

⁷ Copies of certain formulæ which stood for years constantly on his blackboard are shown on this page. His beautiful formal handwriting is well exemplified here.

istically terse, conclusive statement of the object, method, and results "of a series of observations made by a number of different persons and extending over several months." The main general conclusions were: "In all cases the eye was most sensitive to changes in a color slightly less refrangible than that of the sodium line, though this color varied somewhat with different persons, being in some cases more orange and in others more yellow. In all cases the eye was more sensitive to changes in the color corresponding to the F line than to changes in colors lying half way between b and F ." That is, in the part of the spectrum used, from $Li\ a$ to G , the curve of sensitiveness showed, for every eye examined, two maxima. Some eyes were found to be ten times as sensitive to small changes as other eyes. An interesting fact noted is that an observer may be able to see that two slits of light are of slightly different color without being able to tell which of the two colors is the more refrangible. The acoustic analogue is that even a good musical ear may be unable to decide which of two tones, perceived to be different, is of the higher pitch. I dwell somewhat upon these particulars because it seems to me that this careful little paper, based on a considerable body of observations, may be of interest to some investigators of the present time who may have overlooked it. I think, though of this I am not sure, that Peirce was the first to make such a study of retinal sensitiveness by direct use of the spectrum, instead of using revolving colored disks.

Many years later he published two other papers of a kind that might well come from a psychological laboratory. One of these, printed in *Science* for September 29, 1899, is on *The Perception of Horizontal and of Vertical Lines*. The opening paragraphs read as follows:

"Almost every person is occasionally called on to decide by the eye whether some straight line is horizontal or some other line vertical. It usually happens, as, for instance, when one has to set a picture straight on the wall of a room, that the judgment is helped by the presence, in the neighborhood, of other lines, known to be nearly horizontal or vertical, but sometimes all standards are lacking and then the decision is a little more difficult to make.

"In order to find out whether such training as a student in physics gets from several years of laboratory work is likely to improve his

judgment in such matters as these, and whether astigmatism affects the results materially, I have experimented in the Jefferson Physical Laboratory upon forty persons who kindly consented to make observations for me."

Some of the interesting conclusions from this study are given thus :

"Trained observers have smaller ranges [among several trials, all by the same individual] than other people, but their deviations [average errors] are not noticeably small. Astigmatism, so severe as to require the constant use of spectacles [discarded here], does not seem to affect the readings much."

The other paper which I have referred to, published in 1906, was *On the Length of the Time of Contact in the Case of a Quick Tap on a Telegraph Key*. About twenty persons participated in the experiments here described, for Peirce was never satisfied with a small number of any kind of observations. Some of the conclusions were that the average person, pressing down a key and then lifting it, can make a contact as short as one-thirtieth of a second, and that, striking with a thimble on a block, he can make a contact of rather less than one two-hundredth of a second.

I find no research paper from Peirce during the interval between 1883 and 1889, but in the latter year he published, with Prof. R. W. Willson, an article *On the Charging of Condensers by Galvanic Batteries*. The following are two of the opening paragraphs :

"We shall begin by considering the behavior of different batteries when they are suddenly called on to furnish definite quantities of electricity in definite short times, and in this first paper we shall give some results which we have obtained in using water cells.

"These results are interesting, because the water battery possesses in an exaggerated degree some properties which are common to all batteries, and which may seriously affect the quantity of electricity furnished to a large condenser by a cell with which it is connected for a short time only."

The paper describes in detail the method used for making and measuring contacts lasting a small part of a second, and then follow several pages of results and discussion. These results are striking enough. Any one familiar with a water-

cell—a strip of zinc and a strip of copper placed opposite each other in a small vessel containing ordinary tap-water—knows that it is highly subject to polarization, but many may nevertheless be surprised to read that 240 water-cells in series, connected for two seconds with a condenser, put into this condenser less than twice as much electricity when the latter had a capacity of 11.74 microfarads as when it had a capacity of 0.5 microfarad.

Evidently resistance has an important part in such experiments as those here described, and accordingly this paper is followed after a few months by another, from the same authors, entitled *Note on the Measurement of the Internal Resistance of Batteries*. This is very short, only three pages, and, taken with its predecessor, which is eighteen pages long and bears a Roman numeral I, as if it were to be followed by other corresponding parts, gives the impression that the original undertaking of this research was not fully carried out at this time. In fact, I think it may have been the relation and relative size of these two papers that suggested to Peirce the phrase *a portico to my hen coop*; for this expression, or one very like it, he used with reference to some work of his own.

The shorter paper, after stating cautiously the rather surprising conclusion to which the evidence led, ends as follows: "It would be easy to suggest explanations for the results noted here, but we content ourselves with drawing attention to the facts." Such an attitude was highly characteristic of Peirce. Though profoundly versed in scientific theory, he was not a theorizer. His constant effort was to add to our certainties of knowledge. He did not care to contribute to our uncertainties. He was not willing to run the risk of misleading or of being obliged to retract. There is something admirable in this caution, yet I cannot help wishing that in this case, and in some others, he had ventured more.

Many years later, and probably at his suggestion, one of his students, Mr. C. H. Ayres, made the resistance of galvanic cells the subject of his doctorate thesis, and another, Mr. Shuddemagen, studied the phenomenon of residual charge in condensers. It may be that in this way Peirce's original purpose was carried out.

It is a curious fact that no research paper written by Peirce between 1877 and 1891 makes any use of the higher mathematics, and any reader knowing him through these papers only might suppose him to be purely an experimentalist. But the next paper, *On Some Theorems Which Connect Together Certain Line and Surface Integrals*, printed in 1891, shows him in a different light. Doubtless these theorems were discovered and used in his teaching. They were first published in the *London Educational Times*, an arena in which those mathematically endowed are in the habit of exhibiting their own powers and testing the powers of others by solving or proposing ingenious and difficult problems. The first theorem is stated as follows:

"Let U be any function of the two polar coördinates, r and θ , which, with its first space derivatives, is finite, continuous, and single-valued throughout that part of the coördinate plane which is shut in by the closed curve T . Let δ be the angle between the radius vector, drawn from the origin to any point P on T , and the normal to T drawn from within outwards at P . Then, if T does not include the origin, the line integrals of $U \cos \delta$ and $U \sin \delta$, taken around T , are equal respectively to the surface integrals of $\frac{Dr(r, U)}{r}$ and $\frac{D_\theta U}{r}$, taken over the area enclosed by T ."

I shall make no attempt to analyze this or any other of Peirce's purely mathematical papers, for such an effort would be laborious to me and unsatisfactory to my readers. I have, however, quoted this one passage in the hope that it may somehow convey, even to those not versed in the higher mathematics, some idea of the manner in which he moved and made his way in that element. It was a manner of proficiency and power, instantly recognized in any company of eminent mathematicians as proof of his initiation to their fraternity.

We have now seen that Peirce wrote three classes of scientific papers, the purely experimental, the purely mathematical, and a third class in which mathematical and experimental investigation went hand in hand; and we have at least looked at some example of each class. These papers were, as we have seen, infrequent during the first ten years of his teaching at Harvard; but thereafter they were more numerous, too nu-

merous to be mentioned exhaustively, even by title, here. It will be enough if I indicate the range and the general character of his productiveness during the last twenty years of his life.

He continued to publish from time to time brief papers giving the results of observations which he had made incidentally in the course of his teaching or his experimental research, perhaps purely informational, relating, for example, to the properties of certain alloys much used in electrical work, or to the effectiveness of wood and certain other materials as electrical insulators, or to the merits of cast-iron as a material for permanent magnets. A few illuminating sentences from such papers, showing the breadth of the experience on which they are based, are the following:

"I have been obliged, during the last three years, to procure several hundred more or less complicated switchboards, and many of these had to be used in making accurate measurements of electrical quantities. It has been necessary, therefore, to determine under what circumstances hard dry wood or red vulcanized fiber may safely be used, and when marble or ebonite, or even a block of freshly scraped paraffine, is required."

"In preparing a large number of deflecting magnets for the use of students in measuring by Gauss's method the intensity, H , of the horizontal component of the earth's magnetic field, I have had occasion to make several hundred measurements of the induction coefficients of seasoned magnets of different sizes and shapes."

"During the last six or seven years a large number of d'Arsonval galvanometers, in which the permanent fields are due to hardened and artificially seasoned cast-iron magnets, have been used in the Physical Laboratory of Harvard University, in competition with similar instruments furnished with hardened forged-steel magnets from the shops of well-known makers."

So all the immense labor of his routine laboratory teaching, vigorously, alertly, carried, was made to yield lessons of experience communicated to fellow-toilers throughout the world. And it was the same with his teaching of mathematics and mathematical physics. His *Short Table of Integrals*—containing in the edition of 1899 no less than 897 forms, but still, according to him, a *short* table—was a book that, under his hands, wrote itself, to the vast advantage of the rest of us. I think that all of his purely mathematical papers, having no experimental element though applicable to physical problems, grew

out of his teaching, except perhaps the *Table of the First Forty Roots of the Bessel Equation* $J_0(x) = 0$, etc.; and this appeared as part of an experimental research paper which, with Professor Willson, he published in 1898.

In the decade 1893-1903 he returned to and was largely occupied with an experimental study of heat-flow, but now heat-flow in poor conductors, especially slabs of stone. To this difficult and laborious undertaking he brought all the resources of his mature knowledge and skill, together with the remarkable ingenuity of his coadjutor, Professor Willson. The main results obtained are given in two articles—the first, published in 1898, *On the Thermal Conductivities of Certain Poor Conductors*; the second, published in 1900, *On the Thermal Diffusivities of Different Kinds of Marble*. The first of these is a mighty paper. It opens with a tremendous attack, reminding one irresistibly of the heavy artillery fire with which a great modern battle begins, and then follows, what is often wanting in the military analogue, a movement for which every means and instrument has been maturely prepared. If this paper is not widely famous, it is because the scientific world during the past twenty years has not been keenly interested in the mathematical theory of heat-flow or in the specific thermal conductivities of the materials here dealt with.

The mathematics deal broadly with the problem of the final distribution of temperature along the axis of a prism of any uniform material, kept hot at one end and cool at the other, but with a variety of assumed conditions for the temperature of the sides. The results of the experiments are shown in the following quotation:

"Arranging the results in the order of the conductivities of the specimens, we get the subjoined table. We call attention to the two groups of fine-grained marbles, which have conductivities of about 0.0068 and 0.0076 respectively, at about 30° C.

Carrara statuary.....	0.00501
" " 	0.00509
Mexican onyx.....	0.00556
Vermont statuary.....	0.00578
American white.....	0.00596
Egyptian	0.00623
Sienna	0.00676

BENJAMIN OSGOOD PEIRCE—HALL

Bardiglio	0.00680
Vermont cloudy white.....	0.00681
Vermont dove-colored.....	0.00684
Lisbon	0.00685
American black.....	0.00685
Belgian	0.00755
African rose ivory.....	0.00756
Tennessee fossiliferous.....	0.00756
Knoxville pink.....	0.00757
St. Baume.....	0.00761

We reserve for a second paper the results of observations made upon other materials."

The paper on diffusivities, of which the title is given above, dealt with these same marbles. There was no subsequent paper on conductivity bearing the name of both Willson and Peirce. Professor Willson had now become deeply engaged in teaching astronomy, and Peirce went on alone with his researches, publishing in 1899 a paper *On the Thermal Conductivity of Vulcanite*, and undertaking, at the request of the late Prof. Alexander Agassiz, a study of the conductivities of certain pieces of rock from the Calumet and Hecla mine.

The results of this study were published in a brief article in 1903, with the quiet remark, "The determinations involved steady work for several months." In fact, this "steady work for several months," coming at the end of steady work at high pressure for many years, was too much for even his great strength. In 1900 Peirce completely broke down, and for two years he was out of the harness. He has told me that during this period he could do work in mathematics, but not in physics. Indeed, the third edition of his Newtonian Potential Function, a book very largely mathematical, came out in 1902.

He suffered terribly and almost constantly from nausea during these two years—"felt drunk," as he expressed it. After his return to work in 1902, he for a long time walked carefully with a cane and with feet wide apart, when out of doors, and in the laboratory he would move about with his hands against the walls for support; but he gradually regained his strength and poise. Though he never had again the abounding physical energy he once possessed, he was, in the number of papers coming from his pen, more prolific than he had ever

been before. In 1910 he returned to the theory of heat conduction in a brief article from which I take a few sentences:

"The work is straight forward enough, but the computation when the slab is relatively broad is very laborious, and in view of the practical importance of the wall method in determinations of the conductivities of poor conductors of heat, it seems well to record some of the results." "When the ratio of a [the width] to c [the thickness] is large, the double series, which defines W , converges very slowly. Thus to obtain the last number in the table more than one hundred and fifty terms of the series were needed."

I reproduce these sentences to show once more the spirit in which Peirce worked. May the labor that shortened his life lighten the burden of others! This would have been his prayer, and it may well be ours.

Peirce's research work after 1903 relates, for the most part, to magnetism, and he published on the average more than one paper a year in this field. Along with these came a series of papers regarding the instruments of his investigation, ballistic galvanometers especially. It is unnecessary for me to say much here about this work, for the very reason that during the later years of his life Peirce was beginning to be discovered by physicists at large in his true quality, as an investigator whose findings, whether mathematical or experimental, were of fundamental solidity and strength. He was growing in reputation at home and abroad.

He was elected to membership in the American Philosophical Society, the Société Française de Physique, and the Circolo Matematico di Palermo. In spite of his habitual self-effacement and his reluctance to accept the responsibility of office, he became by a sort of inevitableness president of the American Physical Society in 1913. In 1912 he was the representative of Harvard University at the celebration of the two hundred and fiftieth anniversary of the foundation of the Royal Society.

But once more he was working too hard. In fact, he was by temperament incapable of sparing himself. He worked tremendously most of the time, and he never learned the wholesome practice of complete mental idleness during the rest of the time. When there was nothing that must be done, he

would find something to do—some exercise of wits, some prank, perhaps. He was fond of Walt Whitman's phrase, "Loaf and invite my soul"; but he paraphrased it to "Loaf and invite your soul," and the very way in which he uttered it, swiftly and with animation, showed that he had no realization of what loafing is. In the spring of 1913 he was compelled by the state of his health to leave Cambridge a few weeks before the end of the academic year, but he was able to visit England with his family. He went also to Scotland, visiting there the two brothers of Mrs. Peirce, Rev. James Landreth, of Logie-Pert, and Rev. Peter Landreth, of Perth, with whom he had cordial relations of intellectual and moral fellowship.

During the summer news of an ominous character concerning his physical condition reached some of his friends in America. An attack of phlebitis had prostrated him, giving rise to alarming symptoms of the heart. He was urged in a telegram from President Lowell to make his health the first consideration; but he wanted to come back, and he did come back, taking up his regular work in the fall. Evidently he was ill, but he said little about his health, and he seemed even more cheerful than usual. At times after his first great breakdown he had shown evidence of solicitude regarding himself; he had, for example, kept pretty close watch of his changes of weight; but now there was, I fancied, a change in his bearing. I think he knew perfectly well the serious character, the probable outcome, of the stroke that had fallen upon him during the summer in England, and with this grave certainty upon him all nervousness and anxiety seemed to pass away. He planned for future work—he could not tell, of course, just how much he might still be able to do—but he faced all the solemn possibilities of his condition. I will not say that he put his house in order; it had never been out of order; but he steadied himself.

As to the verity of his religious faith and religious life there can be no doubt. The question is whether he ever had anything that could be called religious doubt. At least one who knew him well holds it to be preposterous to suppose that he could have had any trouble of this kind. But to claim for

him such an exemption is to put him into a company where, as a thinking, intelligent man, he would stand alone, Saint Paul himself not being able to qualify for membership therein. In fact, his sympathetic nature must have been peculiarly subject to one kind of religious perplexity, the problem of the existence of evil, of suffering that seems needless, a question that has vexed the devout of all ages.

During the Christmas recess of 1913 he once more, and for the last time, fell acutely ill. He bore the terrible suffering of the next two weeks with unbroken fortitude, with unwearied consideration for his attendants, and he met death in a spirit of serenity and courage.

I cannot better sum up the impression which his personality and his life made on those who knew him well than by adding here an extract from the *Minute* placed on the record of the Faculty of Arts and Sciences of Harvard University, February 17, 1914:

"He has left among us a large place, which no other man can fill, and when the question is asked, how we shall now fare without him, we can only reply, better than if we had never had him; for he was constructive, and he builded well. He was one of those of whom it can be said: 'They may rest from their labors and their works do follow them.'"

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1899. 1. The perception of horizontal and vertical lines.
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Cleveland Abbe.

CLEVELAND ABBE

1838-1916

BY W. J. HUMPHREYS

Cleveland Abbe's influence on the progress of pure science and its application to the public welfare was so varied and so great as to make it important that we know who he was, the conditions under which he worked, and what he accomplished.

A portion of Professor Abbe's genealogy, enough perhaps for the present purpose, is briefly as follows, in direct descent. And here, at the very beginning of this sketch, I must acknowledge my indebtedness to Abbe's patient labors, for this summary is gathered from his posthumous book, the *Abbe-Abbey Genealogy*, a monumental work that for nearly 60 years was his absorbing recreation and hobby.

1. John Abbe, born in central England about 1613, came to America on the *Bonaventure* in 1635 and settled first at Salem, Mass., but soon moved to Wenham, near by, when that town was established.

2. Samuel Abbe, who in 1692 was among those in Salem opposing the fanatical persecutions for witchcraft.

3. Ebenezer Abbe, of Windham, Conn., spoke for the community in 1717 to the Assembly in a petition that property taxes be applied to the establishment of their church.

4. Joshua Abbe, of North Windham, Conn., was a large land-owner, about 1740, and a strong religious leader of a Baptist sect that became known as Abbeites.

5. Phineas Abbe, a citizen of Windham Township, Conn., had for a time during the Revolutionary War the custody of some English prisoners.

6. Moses Cleveland Abbe married Talitha Waldo, a descendant of prominent civil and military colonial officers.

7. George Waldo Abbe, deacon in the Madison Avenue Baptist Church of New York, merchant and philanthropist, mar-

ried Charlotte Colgate, who came of a line of Dissenters registered at Leyden in 1610-1620.

8. CLEVELAND ABBE, 1838-1916, subject of this sketch.

Walter, 1841 —, for many years head chemist of the Atlantic White Lead Works.

William, 1843-1879, died from after-effects of a wound received at Gettysburg.

Charles, 1849-1917, inventor, and for some years an assistant examiner in the U. S. Patent Office.

Robert, 1851 —, eminent surgeon in New York.

Helen, 1853 —, married Hubert Howson of New York.

Harriet, 1855 —, single, New York.

9. Cleveland Abbe, Jr., 1872 —, meteorologist and editor of the Monthly Weather Review.

Truman Abbe, 1873 —, surgeon, Washington, D. C.

William Abbe, 1877 —, patent attorney, New York.

10. Several children: of Cleveland, one son; Truman, two sons and two daughters; William, three sons and three daughters.

Professor Cleveland Abbe was born on Madison street, New York City, December 3, 1838, and died at his home in Chevy Chase, Md., October 28, 1916, from effects incident to the malignant degeneration of a mole, which had rapidly become so extensive as to prevent his resting comfortably in other than one position. For more than a year he had also been afflicted with partial paralysis of the right side, but this, from which he had largely recovered, never in any wise affected either his mind or his cheery hopeful disposition nor, apparently, at all hastened the end.

Professor Abbe's preliminary education was obtained, first, in private schools and, later, in the David B. Scott Grammar School, No. 40, on 20th street, New York. His academic training was acquired at the New York Free Academy, now the College of the City of New York, which he entered in 1851, and from which he was graduated with distinction, obtaining the degree B. A. in 1857 and M. A. in 1860..

But this formal education was abundantly supplemented by extensive reading on all manner of subjects. Nor did he ever lose his interest in every branch of human knowledge, nor

✓ cease to read, or at least desire to read, everything printed that by any chance could be worth reading. In reference to this characteristic an admiring friend, writing of him as he knew him in his later life, says :

“From the first I was impressed with his broad interests, extending not only outside of meteorology and astronomy to the other sciences, but to philosophy, art, and literature. His knowledge was very broad ; his reading comprehensive. I remember, when living at his home, seeing him very early in the morning sitting in his library reading the *Encyclopedia Britannica*. He told me that he was reading it through consecutively.”

During his school days he had the advantage of spending his summer vacations in the country with his grandfather, Moses Cleveland Abbe, near Windham, Conn. On these occasions the future meteorologist, it is said, sometimes found it more pleasant to loll in the shade and contemplate on the beauty and mysteries of the floating clouds than to help his worthy ancestor with the exacting duties of the farm. But the youthful dreamer was ever subject to the old gentleman's wholesome admonition to the effect that “boys that don't work don't eat,” and so it happened that these summer vacations furnished both healthful exercise and abundant opportunity to get acquainted with many natural phenomena of absorbing interest.

Early in his life, indeed when he was only eight years old, there happened a trivial occurrence which perhaps should be recorded, as it seems to have had an important influence on his entire intellectual career. This was the gift to him by his mother of “*Smellie's Philosophy of Nature*,” a remarkable book by the editor and in great part author of the first edition of the *Encyclopedia Britannica*. This he pored over as a boy, kept sacred in his library throughout the whole of his active career, and so frequently and feelingly alluded to during his last illness that in loving tenderness it was placed in his hands as a fit companion during his long rest beneath the oaks and the roses of beautiful Rock Creek Cemetery.

Professor Abbe was twice married and on each occasion most happily. His first marriage, May 10, 1870, was to Miss Frances Martha Neal, daughter of David Neal of Cincinnati.

Practically all their wedded life, terminated by death on July 24, 1908, was spent in that historic old mansion, once (1817) the "White House," 2017 I Street N. W., Washington, D. C. which they owned, where they entertained their numerous scientific and other friends, and where, dearest of all to them, they reared with every thoughtful care their three sons, Cleveland, Jr., Truman, and William.

His second marriage, April 12, 1909, was to Miss Margaret Augusta Percival, of Basseterre, St. Christopher, B. W. I., under whose constant care and unfailing devotion the remainder of his useful life was most happily spent.

In religion Professor Abbe was always devout and sincere, and saw only the good in every Christian creed. Though a member of the Baptist Church from the age of 15, and devoted to its earnest simplicity, he nevertheless loved the beautiful ritual of the Episcopal Church, in which, especially during his later years and in company with his second wife, he frequently found inspiration and comfort. To him form in religious worship, apart from its æsthetic appeal, was of small matter, so long as the sincerity and the substance were the same.

As already stated, Professor Abbe was graduated from the New York Free Academy (College of the City of New York) in 1857. During 1857-'58 he was tutor of mathematics, a subject of which he was very fond, in Trinity Latin School, New York. The following year, 1859, he was an assistant professor of Engineering in the Michigan Agricultural College; and later, 1859-'60, tutor in Engineering at the University of Michigan, where he found in Professor Brünnow an inspiring instructor in Astronomy, the Science whose marvelous revelations had, above all others, aroused and directed his youthful aspirations.

Near the close of his year at Ann Arbor stern duties arose, and Abbe responded in April, 1860, to Lincoln's first call for volunteers. For a few weeks he was tried out at a recruiting camp, but finally, to his severe disappointment, rejected because of excessive myopia, an affection that debarred him from youthful games, forbade him a soldier's service, and all his life long restricted his pleasures and limited his opportunities. Though rejected as a soldier he nevertheless served

his country during the years 1860-'64 by assisting Dr. B. A. Gould at Cambridge, Mass., in the telegraphic longitude work of the United States Coast Survey. Presumably it was this practical work with Dr. Gould that led to his spending the next two years, 1865-'66, as a guest or supernumerary astronomer at the Observatory of Pulkova, near Petrograd, noted for its contributions to applied astronomy, and then under the direction of the famous Otto Struve. Here he found not only congenial work but also pleasant companions and the good cheer of warm hospitality. In this happy atmosphere his sympathetic nature found such peace and content as to cause him always to remember Pulkova as a scholar's paradise!

On his return to the United States Professor Abbe accepted, in 1867, the position of aid in the U. S. Naval Observatory; but shortly afterwards, on February 1, 1868, assumed the responsible duties of director of the Cincinnati Observatory, to which he began giving his entire time on the 1st of June. The inclusiveness of his plans on taking charge of this observatory was set forth in his inaugural report, June 30, 1868, to the Board of Control, in which he says:

"If the director be sustained in the general endeavor to make the observatory useful, he would propose to extend the field of activity of the observatory so as to embrace, on the one hand, scientific astronomy, meteorology, and magnetism, and, on the other, the application of these sciences to geography and geodesy, to storm predictions, and to the wants of the citizen and the land surveyor."

This generalized plan he then elaborated into a scheme, magnificent in scope and noble in purpose, but out of all possible proportion to a one-man observatory whose chief function hitherto had been that of entertaining the public. His disposition always was so hopeful that, apparently, he seldom took into consideration such obstructive factors as lack of time or want of opportunity. But if, perhaps, this accounts for his beginning some things that were never completed, it doubtless, on the other hand, also accounts for the completion of many things that otherwise might never have been begun.

During his directorship of the Cincinnati Observatory, however, Professor Abbe's active interests, in spite of his all-inclusive program, soon turned more and more to meteorology, and

especially to that eminently useful application of it by which warnings may be given of approaching storms. He was much interested in the fact that telegraphic circuits were then generally made up so as, presumably, to be least disturbed by storms as indicated by the morning reports from many stations, of the weather, height of the barometer and direction of the wind. This demonstration of the value and practical use of weather predictions aroused in him an impatient desire, born of earnest conviction, that the great benefits of storm and flood warnings be extended to the entire public and all its industries. Accordingly, on July 29, 1868, he addressed the following letter to the president of the Cincinnati Chamber of Commerce:

"Mr. JOHN A. GANO,
President, Cincinnati Chamber of Commerce.

"DEAR SIR: I take the liberty of bringing to your attention, and through you to that of the Associated Press, a plan of operations looking to a system of storm warnings such as will, I believe, be highly appreciated by the public.

"It cannot have escaped your notice that during the past 20 years very many endeavors have been made by various nations to utilize the science of meteorology. From the Paris Observatory daily bulletins are published showing the state of the weather in western Europe. In England storm warnings are published many hours in advance and sent to the ports that are threatened.

"The great value of such storm warnings long ago suggested the importance of the study of the phenomena of our own climate, and these labors have met with commensurate success. But such endeavors must be long continued and not spasmodic, and in view of their importance I take the liberty of suggesting a simple plan by which the Associated Press may contribute much towards the progress of the science of meteorology as well as towards its utilization.

"The Cincinnati Observatory, because of its central position with reference to the railroad and the telegraph systems of our country, may with special propriety be made the central station for meteorological dispatches from all parts of the country. The newspapers daily publish such dispatches from ten to fifty stations, and it is suggested that if the Associated Press will substitute for these far more accurate and valuable observations of the trained meteorological observers stationed all over the country, and will forward them to this observatory, we will submit them to a careful discussion, and will within a few hours return them systematically arranged and condensed to the Associated Press. In this shape they will be of increased value to all who consult them.

We shall, moreover, ourselves enter these observations upon an appropriate manuscript chart, and propose that when we send the daily digest of the weather to the Associated Press we accompany it with such general predictions of the weather for the next two days as we may seem authorized to venture upon.

"It seems certain that, at least in the case of a great storm, we may arrive at a greater degree of certainty in these predictions than is attained in England and France, where only three-tenths of the predictions are verified.

"Such a system as we propose would, it is believed, powerfully contribute to advance science and practical meteorology.

"We have received promise of the hearty coöperation of the observers of the Smithsonian Institution and of the army in case the systematic daily publication of good observations and storm warnings is attempted.

"To render these meteorological reports as simple and brief as possible consistent with accuracy, a series of blanks will be issued to each observer, who will each day at an appointed minute (8 a. m., Cincinnati mean time) record the following data:

"a. Barometer reduced to 2 degrees and to a common standard.

"b. Temperature of the free air.

"c. Amount of moisture in the free air.

"d. Direction and force of the surface wind.

"e. Quantity of lower clouds, kind, and direction of motion.

"f. Quantity of upper clouds, kind, and direction of motion.

"g. Amount of rain or snow during the past 24 hours.

"h. Condition of the atmosphere (clear, hazy, foggy, etc.).

"Further instructions will be given to the observers by which the dispatches from each will average twenty or twenty-five numbers or letters. Observers of the requisite experience can readily be found in all desired localities. They should be distributed widely over the country. If not found at any desirable place, then the telegraph office at that point will be supplied with the proper instruments, and some employee of the company instructed in their use, the company being responsible to the extent of \$100.00 for the value of the instruments. The observers will send their blanks to the nearest telegraph office addressed to the 'Cincinnati Observatory,' and we must receive them all at the Cincinnati office of the Western Union Telegraph by 12 o'clock noon. Should there be no communication with any station, we are to be informed of the fact, and the delayed dispatches are to be forwarded at the earliest opportunity. These dispatches are to remain and be the property of the Cincinnati Observatory. The observers will furnish their observations gratis, receiving in return a copy of the daily bulletin or summary in a form convenient for preservation.

"The daily digest and the weather predictions are to be furnished by the Cincinnati Observatory gratis to the Associated Press and to such

institutions as unite with us in our undertaking. At least 100 stations ought to be thus occupied and report daily. If the Associated Press will assume the expense of 50 daily dispatches, it will not be difficult for us to secure the coöperation of other interested parties who will afford the means of largely increasing the number of daily dispatches.

"Hoping that this or some improved plan may commend itself to your attention,

"I remain very respectfully yours,

"(Signed)

CLEVELAND ABBE,

"Director Cincinnati Observatory."

After much consideration of this proposition Mr. Gano requested Professor Abbe to send him a second letter that could be presented to the Cincinnati Chamber of Commerce. The following is a copy of the "rough notes" of the second letter, and Fig. 1 is from a photographic copy of the sketch referred to, which, however, is not in Professor Abbe's handwriting:

"CINCINNATI OBSERVATORY, May 7, 1869.

"JOHN A. GANO, ESQ.,

President, Cincinnati Chamber of Commerce:

"As the changes in the weather have so important a connection with many branches of business, and especially with agriculture and navigation, it has by many been considered very desirable that the science of meteorology should be utilized by attempting to draw therefrom some predictions as to the state of the weather in the future. In order to meet this want, I propose to inaugurate such a system by publishing in the daily papers a weather bulletin which shall give the probable state of the weather and river for Cincinnati and vicinity one or two days in advance.

"These predictions will be based upon a system of telegraphic dispatches received from proper observers stationed at various distances from the city, and the accuracy of the predictions, etc., will increase from month to month and year to year, in proportion as we are able to increase the number of our stations. For many years a system of storm predictions has been kept up in France and England, and this has, during the past three years, been extended with great success to India. This system is under the special care of the British Board of Trade, and is recognized as of eminent usefulness, the predictions failing only in a small percentage of the cases. As Cincinnati is very favorably situated with respect to the proposed outlying stations, it is most probable that 90 per cent of our weather predictions will be verified. It is thus evident that we do not propose to guess at the weather, but (leaving that to the almanac makers) we shall be able to assert with confidence the nature of the weather for one, two, or four days in advance, as well as the stand of the water in the river.

Albany

Dehague
425

Chicago
250

Deloit
250
Tulado
250

Cleveland
275

B. Hall
400

Brooklyn
600

50000

D. H.
Wherry
200

St. Paul
580

Des Moines
580

St. Louis
300

Cincinnati

Abingdon
225

Carip
275

Richville
225

Memphis
400

Chattanooga
300

Vicksburg
575

Selma
475

sample dispatches

Barom reduced to 32° — 29.372

Dry therm — — — 53.3

Wet therm — — — 47.14

raining rain/fall } — no rain
snow/fall }

Clouds lower

time

cumulus

base

N. E

upper lines

3

air

W

Wind direction

N. E

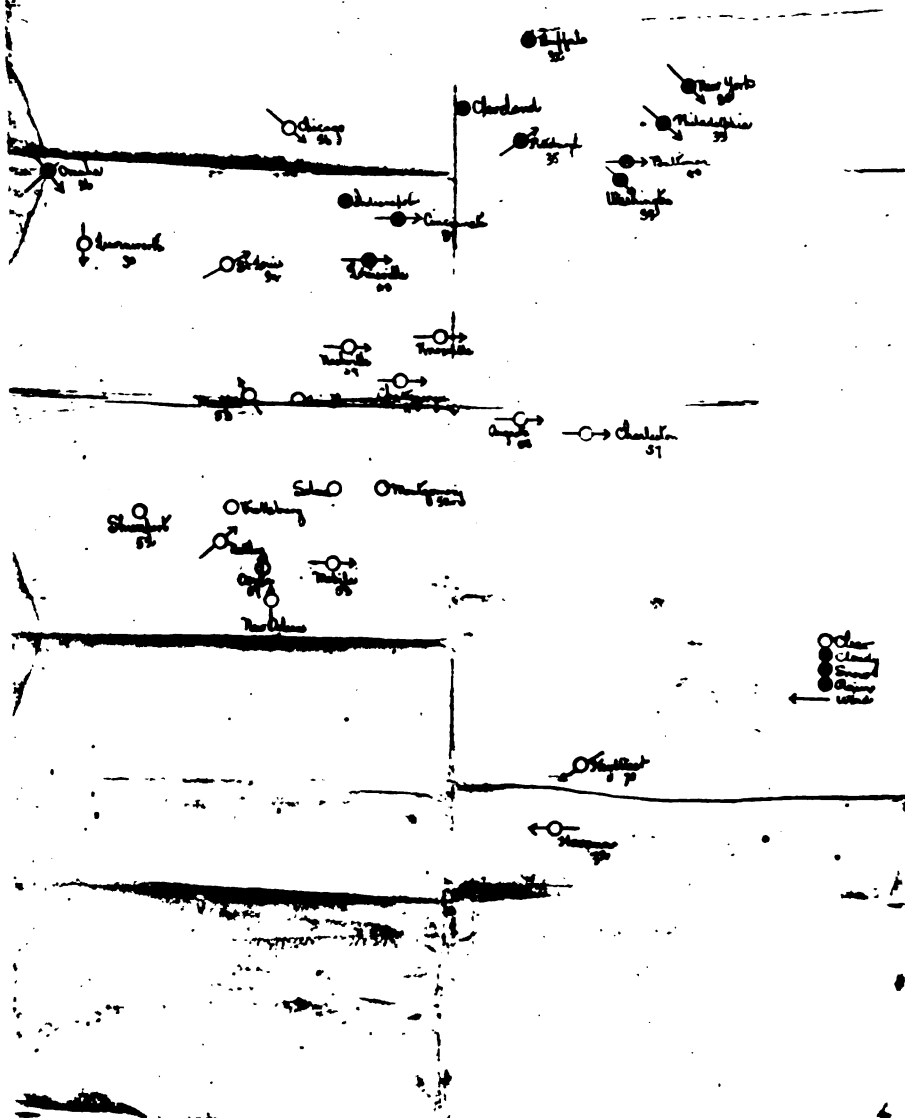
3

Time when storm began
whether the weather turned
with rain or

Total average 25 words.

Western Union Telegraph Co. Western Report

Monday February 28, 1899



"The expense of the proposed system will arise in the first place from the furnishing of the stations with instruments and the cost of the telegraphic dispatches, and again in the method of publishing the predictions. As to the former, the furnishings for the stations, in order to inaugurate the system, will be \$500; the telegraphic dispatches, per year (365 x 10, at 25 cents), \$900; the total will not exceed \$750 or \$1,000.

"Should the Chamber of Commerce support this undertaking, it would be very proper that besides the publication in the morning papers there should be hung up in the Exchange a chart of the country, showing at a glance the condition of the weather at a given moment."

This copy is without signature being attached. A notation by Professor Abbe says:

"The original draft adds a sketch of twenty stations, and a sample form of telegraphic dispatches, estimated to not exceed twenty-five words, but I am not sure that these were sent to Mr. Gano in this letter. They were submitted to the committee of the Chamber of Commerce a few days afterwards."

The immediate results of this appeal are best told by the following quotation from Professor Abbe's report of June 18, 1870, to the Board of Control of the Cincinnati Observatory:

"The importance of anticipating the changes in the weather, especially storms or droughts, was alluded to in my report of June, 1868. This subject having been brought by myself to the attention of the Chamber of Commerce of this city, that body, in June last [1869], authorized me to organize a system of daily weather reports and storm predictions. Experienced observers at distant points offered their gratuitous coöperation. The Western Union Telegraph Company offered the use of their line at a nominal price. The bulletin began to be issued September 1, in manuscript form, for the special use of the Chamber of Commerce, and began to be printed a week later as an independent publication.

"This bulletin was supported for three months, as at first agreed on, by the Chamber of Commerce; its conduct then passed entirely into the hands of the observatory, and has thus continued until the past month. The independent publication of the bulletin was, however, discontinued, and it has, since December 1, only appeared in the morning papers. The daily compilation of this bulletin for the newspapers was undertaken two weeks ago by the Cincinnati office of the Western Union Telegraph Company, and will so continue, thus relieving the observatory of all further responsibility.

"In February the manager of the Cincinnati office undertook the publication of a daily weather chart [Fig. 2 is a copy of the chart for

February 28, 1870], and the favor that this has met with insures its continuation in the future. The Daily Weather Bulletin and Chart are, therefore, now supported solely by the Western Union Telegraph Company, and must be considered as a very important contribution to meteorology. It would have been highly to the credit of the observatory could these publications have been maintained in its own name; but this was impossible, owing to the want of funds and assistants."

The bulletins for September, October, and November, 1869, were prepared by Professor Abbe, written on manifold paper by clerks in the Western Union Office and delivered by the messengers, and known as "greasers."

Professor Abbe's justifiable enthusiasm over his success in foretelling the coming of storms may be inferred from a letter to his father in which he said: "I have started that which the country will not willingly let die."

This statement did not refer, of course, to the collection of meteorological data, nor to the construction from telegraphic reports of maps showing the current state of the weather over the country, both of which had been done by the Smithsonian Institution under the direction of Joseph Henry some 20 years earlier, but rather to the systematic daily forecast from such maps of the *coming* weather. And his estimate was correct, for the time was so ripe for a National Weather Service that less than six months after the first Bulletin of the Cincinnati Observatory was issued, the Federal Government through a Congressional resolution signed by the President February 9, 1870, authorized the creation of a Weather Service, and placed it under the immediate direction of the Signal Service.

On putting this law into operation the Secretary of War sought the services of Prof. I. A. Lapham of Milwaukee, Cleveland Abbe, then of Cincinnati, and others. Professor Lapham, through his persistent advocacy of storm warnings for the benefit of commerce on the Great Lakes, had been influential in securing the Federal action that established a National Weather Service. Therefore, and also because of his knowledge of the subject, he was offered the position of Assistant to the Chief Signal Officer at Washington. Private considerations, however, kept him from coming to Washington, but he did consent to act for a time in this capacity at Chicago.

Professor Abbe, the only man in the country who, before the establishment of this Service, had had experience in practical weather forecasting for the public, was then appealed to, and finally consented to serve in the position Lapham had been unable to accept, beginning on January 3, 1871. At first he had expected to resign at the end of three years, the term of his appointment, but instead of doing so he continued in this Service without interruption, through various trying circumstances, until June 4, 1915, when, owing to ill health, he took a year's furlough. Being still unable to assume regular duties, he resigned on August 3, 1916. During about half of this time, or from August, 1893, his principal work had been the extremely useful and congenial one of editing the meteorological journals of the Weather Bureau—the *Monthly Weather Review* and the *Mount Weather Bulletin*.

The following delightful story of Abbe's connection with the Weather Bureau during its formative period has been put at my disposal by Prof. T. C. Mendenhall. It is given in its entirety because of its general interest, and also because it covers the most active period of Professor Abbe's career:

"Although the years of my acquaintance with Professor Abbe were nearly fifty in all, my intimate association with him began about a third of a century ago. It was in the 'early eighties' of the last century, when the Weather Bureau was the Signal Corps of the Army or the Signal Corps was the Weather Bureau, both modes of stating the relation of the two being essentially correct, as for many years the operations of the Signal Corps were practically restricted to its activities as a weather forecasting service. In order to understand and appreciate the almost unique combination of qualities, moral and intellectual, which enabled Abbe to play his great part in the creation and development of what is in many respects the most important of the scientific bureaus of the Government, it is necessary to know something of the conditions under which he worked during the earlier stages of that development.

"At thirty years of age, as the enthusiastic director of the Cincinnati Observatory, he had successfully inaugurated a system of weather reports by telegraph from which daily forecasts were attempted. His success led to an act of Congress providing for the utilization of the Signal Corps of the army for the organization of a general weather service, and Professor Abbe was called to Washington as meteorologist in that service. At that time he was the only man in the country having experience in or knowledge of weather forecasting for the use of

the public based upon the principles of scientific meteorology, and for some time the duty of daily interpreting the meteorological observations made in all parts of the country devolved upon him alone. The new service was immediately popular, and though barely thirty years of age, he soon became generally known as 'Old Probabilities,' or 'Old Prob.' Realizing that the then state of our knowledge of meteorology was quite inadequate for anything like accurate forecasting, he sought to induce the War Department to obtain an annual appropriation for the purpose of maintaining a systematic study of the subject, both theoretical and experimental. Methods of transacting business assumed to be necessary in a military organization in time of peace are decidedly inimical to scientific investigation and research, and from the start Abbe's plans met with obstruction at almost every turn, not always due to unfriendliness—indeed, more often to mere inertia of the system. In overcoming this opposition, which at times was so unyielding as to completely discourage all others who were interested, he was successful, because his two most characteristic traits were an inexhaustible enthusiasm for the work, which amounted almost to an obsession, and an equally inexhaustible patience in meeting unfriendly or unintelligent criticism.

"I think not much was actually accomplished until Gen. W. B. Hazen became Chief Signal Officer in 1880. For the two great advances made during the first few years of his administration credit belongs to Abbe, almost if not quite alone. Certainly the initiative and general plans were his, though, of course, there could have been no success without the friendly support of the Chief Signal Officer. Perhaps the most important of the two was the improvement of the character of members of the corps by means of a provision for special enlistment of young men, mostly college graduates, with the rank of sergeant in the Signal Corps, with exemption from most of the ordinary duties of the regularly enlisted soldier.

"The other was the establishment of what was known as the 'Study Room,' in which all meteorological problems arising in the service were subjects of investigation by civilians employed for the purpose, two or three of whom had the rank or title of 'Professor' and some others that of 'Assistant Professor,' an arrangement probably suggested by the practice of the military and naval academies. This was shortly supplemented by the establishment of a laboratory for experimental investigation, the inauguration of which I undertook at the earnest solicitation of Professor Abbe in 1884.

"The study room and the laboratory formed, also, a sort of school for the enlisted men, to whom courses of lectures on meteorological, physical, and allied topics were given. The distinguished meteorologist, William Ferrel, was one of the professors, and in addition to a part in the instructional work his assignment embraced a theoretical investigation of the general principles of meteorology with a view

to the improvement of the work of forecasting the weather. The vitalization of the service through these important changes resulted, happily, in the acquisition of such young men as Marvin, Fassig, McAdie, Morrill, McRae, Russell, and a number of others, some of whom are still in the service, and from several of whom have come in later years contributions to the science of meteorology of very great value.

"The difficulty of doing scientific work, either theoretical or experimental, under conditions then existing, can be appreciated only by those who have attempted it, and it is because of Professor Abbe's extraordinary courage and success in meeting these difficulties that I am referring to them at such length. There was at that time a sort of a tradition among military men—which may not yet be extinct—implying that a properly signed written order from a superior officer to do a certain thing carried with it not only the duty of doing it, but also the *capacity* to do it, which I imagine may be a rather stimulating idea for one engaged in battle, though of doubtful value in scientific research.

"Our duties were assigned to us in regular instructions or 'orders' from the Chief Signal Officer, written on regulation order slips on which our initials were placed, as evidence that we had received and understood our instructions.

"The headquarters of the Signal Corps were at that time on 'G Street,' near the War Department, and by a curious chance the two somewhat conflicting elements were housed on opposite sides of the street, the study room, the laboratory, the instrument testing division, etc., being in one building on the south side, while the offices of the Chief Signal Officer and his military aides, the property and disbursing officer, the forecasting officers, etc., were on the north. That controversies between the two were on the whole rather infrequent and rarely acute was due, more than to anything else, to Abbe's unfailing good nature and general willingness to be the subject of the obloquy of both sides.

"The military tradition I have referred to above did not harmonize with the traditions and practice of scientific research. The most industrious and enthusiastic investigator would be somewhat dismayed by the receipt of 'instructions'—not much unlike the following: 'You will begin on Monday next an investigation of the cause or causes of the attraction of gravitation, and make a preliminary report upon your work in two weeks. A final report is to be ready by the first of next month.' Unfortunately Nature does not yield her secrets in response to orders, and there were naturally many failures to 'get results' on time. For example, to Abbe was assigned the preparation of a text on the general subject of meteorology, and his failure to produce a certain number of pages in a given time would be the subject of much fault-finding from 'across the street,' where it was often thought that the study room was not 'paying its way.' The Chief Signal Officer, General Hazen, although first of all a soldier from the time of his admis-

sion to the West Point Military Academy to the day of his death, was by no means unfriendly to scientific men and their work. His attitude was frankly one of open-mindedness, desiring only, like the traditional Missourian, to be 'shown.' But it was not always easy to show him that, although nothing tangible had been accomplished during the past month, the time had not been wasted. He had great confidence in and admiration for Professor Abbe, consulted him freely, and was often guided by his advice when it did not agree with that of his military aides. But in spite of this fact, occasionally when some one would succeed in convincing him that there was too much unproductiveness across the street, he would call Abbe, and, according to an 'office legend,' after emptying the vials of his wrath upon him, would immediately send an official note to the Secretary of War recommending an increase in his salary. In the offices having charge of the disbursement of funds, and of the 'property' of the service, there was little sympathy with the work across the way, and great discouragement to those engaged in it was often the result. The amount of 'red tape' that had to be unwound before the smallest expenditure could be made, together with the fact that the necessity for such expenditure must be shown to an officer quite ignorant of the nature of the work, whose merit was measured by the expenditures he prevented, was often extremely disheartening, and, in fact, it is correct to say that the scientific work of the Weather Bureau was at that time almost continually on the defensive, existing only on sufferance. Indeed, this was in some degree true of all the other so-called scientific bureaus of the Government. Happily it is a condition that has now almost, though not yet entirely, disappeared.

"Certainly if the workers in the study room and in the laboratory were not kept busy enough, it was no fault of Abbe's. He had a singularly full and complete knowledge of the state of the science of meteorology in all parts of the world, and was continually suggesting problems that he thought demanded attention. He usually made a short visit in the laboratory every day, and it was humorously regarded as a disappointment when he did not bring us at least one new subject for experimental investigation. One of his most outstanding traits was the absolute absence of anything like envy or jealousy in his relations with his fellow-workers and scientific men generally. He was quick to recognize a meritorious performance or a meritorious person, and, generous in praise as he was, also at times free in criticism. His disposition was most amicable; he was one of the most lovable men that I have ever known. There was a rare simplicity and frankness in his speech which was reflected in his acts, and added much to the charm of his personality. One could always feel sure that there was no *arrière pensée*; but he was most considerate for the feelings of others, and never intentionally wounded by word or deed. During his long career in the service of the Government, covering nearly half a century,

he passed through many trying situations. The work in which he was engaged was more than once 'under fire,' but passing years have only emphasized the importance of that work with a more general recognition of our great indebtedness to Abbe as the real founder.

"When one considers the small beginning in 1869 at the Cincinnati Observatory, with a few daily telegrams generously donated by the Western Union Telegraph Company, a local forecast printed in a single daily newspaper, and then turns to the present splendid organization, with its thousands of observers, its two or more daily forecasts printed in every city and town, and reaching by telephone or otherwise the remotest corners of the country, its storm warnings, its frost and flood warnings by which annually property worth many millions of dollars is saved from destruction, its important investigations in the field of agricultural meteorology and its other useful functions, one cannot avoid the conclusion that the nation has had few more useful servants than Cleveland Abbe."

Of the many useful rôles Professor Abbe played in the drama of his day perhaps on the whole the most serviceable were those of mentor and propagandist. For years he took a prominent part in the agitation for a system of standard time that finally led to the present compromise of partial order. He also urged the establishment of climatological and meteorological services by the individual States, and had the pleasure of seeing many of them adopt his suggestions. In aid of the student all that was then known of meteorological instruments and methods was compiled in one convenient and invaluable manual; a bibliography of meteorological literature was begun and in great measure completed, and the best papers on dynamical meteorology assembled in two volumes—*The Mechanics of the Earth's Atmosphere*. Finally, by conversation, publication, translation, and countless private letters, he strove, and effectually, to create an active interest in the science of meteorology, and to enlist in the solution of its innumerable problems students of the research type—keen of intellect and persevering. The persistence of his efforts to this end and their eminent success are well described by Prof. R. De C. Ward, of Harvard University, who says, in part:

"I remember Professor Abbe as always keenly interested in the work and progress of young men who were looking towards meteorology, either as a career or only as a passing subject for study. He must have written hundreds of letters of the kind that he often wrote to me,

giving encouragement, suggestion, help. I wrote him once, at the beginning of my own professional career, when I was greatly discouraged and about to turn in some other direction for a livelihood. Professor Abbe wrote me a letter so full of encouragement, urging me so strongly to 'stick to my job,' and assuring me that all would come right in the end, that I gave up my idea of abandoning meteorology. I think Professor Abbe's letter was really one of the turning points in my life.

"Professor Abbe was always keenly and actively interested in promoting sound meteorological education, especially along mathematical and physical lines. He used to write me long letters, outlining problems for young meteorologists, and urging me to establish a school of meteorology, where experts could work together on various atmospheric problems. These schemes of his always seemed most highly visionary to me, but I enjoyed the enthusiasm of Professor Abbe's letters and found a stimulus in them.

"I found Professor Abbe ready at all times to answer any questions, no matter how much time these answers might require. I wrote him freely for years, and I spent many hours trying to decipher that highly characteristic and almost illegible handwriting of his. But this time was well spent, for he never sent me a letter that did not contain something of distinct value and help.

"The qualities which, I think, impressed me most were his wonderful patience; his enormous fund of all sorts of meteorological knowledge; his never-failing willingness to help every one who came to him for information or advice; his modesty in everything that concerned his own accomplishment; his splendid enthusiasm and his desire to impart that enthusiasm to all his fellow-workers in meteorology."

Naturally many honors came to Professor Abbe, two of which, the Symons Memorial Gold Medal, bestowed by the Royal Meteorological Society of Great Britain, in 1912, and the Marcellus Hartley Medal, awarded by the National Academy of Sciences, April 18, 1916, were of inestimable value to him, typifying respectively, as they did, eminent success in his chosen science, and in its application to human welfare.

As just stated, his honors were many; so also were the positions of trust he held and the learned societies of which he was a member. Similarly the causes of these honors—the papers and the memoirs he wrote—are exceedingly numerous. Ordinarily it would be difficult now to obtain a full list of all these honors, societies, et cetera, and well nigh impossible to compile a complete bibliography. But here again Professor Abbe's methodical care is of great service, and therefore the

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following lists, and the accompanying selected bibliography, kindly made up by Dr. Cleveland Abbe, Jr., from his father's abundant notes, are submitted with the belief that with the exception of numerous editorial comments, but little of importance has been omitted.

COLLEGIATE DEGREES HELD

- 1857. B. A., Free Academy, *now* College of the City of New York.
- 1860. M. A., Free Academy, *now* College of the City of New York.
- 1889. LL. D., University of Michigan (honorary).
- 1891. Ph. D., College of the City of New York (honorary).
- 1896. LL. D., University of Glasgow, Scotland (honorary, on occasion of Lord Kelvin Jubilee).
- 1900. S. B., "as of 1864," Harvard University, Cambridge, Mass.

COLLEGIATE POSITIONS HELD

- 1857-58. Tutor in Mathematics, Trinity School, New York, N. Y.
- 1859. Assistant Professor of Engineering, Michigan State Agriculture College, Lansing, Mich.
- 1859-60. Tutor in Engineering and Mechanics, University of Michigan, Ann Arbor, Mich.
- 1884-1916. Professor of Meteorology, Corcoran Scientific School, Columbian (George Washington) University, Washington, D. C.
- 1896-1916. Lecturer in Meteorology, Johns Hopkins University, Baltimore, Md.

OFFICIAL POSITIONS HELD

- 1860-1864. Aid in U. S. Coast and Geodetic Survey (doing astronomical work at Cambridge, Mass., under B. A. Gould).
- Dec., 1864-May, 1865. Resident guest at Nicholas Central Observatory, Pulkova, near Petrograd.
- May, 1865-Sept., 1866. Ausserétatmässiger, or Supernumerary Astronomer at Nicholas Central Observatory, Pulkova, near Petrograd.
- 1867-68. Aid at U. S. Naval Observatory, Washington, D. C.
- 1868-73. Director, Cincinnati Observatory, on Mt. Adams.
- 1871-91. Professor of Meteorology and Civilian Assistant in the office of the Chief Signal Officer, U. S. Army.
- 1891-1916, Aug. 4. Professor of Meteorology in the U. S. Weather Bureau, Department of Agriculture.
- 1892-1909, July. Editor of *Monthly Weather Review* of U. S. Weather Bureau.
- 1909, May-Oct. Official in Charge, Local Office Weather Bureau, at Baltimore, Md.

NATIONAL ACADEMY BIOGRAPHICAL MEMOIRS—VOL. VIII

Oct., 1909-1913. Editor of *Mount Weather Observatory Bulletin*, various residences.

Jan., 1914-1916, Aug. 4. Editor of *Monthly Weather Review*.

MEMBERSHIP IN COLLEGE FRATERNITIES

1856-1916. Member of "Alpha Delta Phi," Manhattan Chapter, Class ['57 ?].

1896-1916. Member of "Phi Beta Kappa," New York Gamma Chapter, Class —.

MEMBERSHIP IN SCIENTIFIC AND LEARNED SOCIETIES

1864. Boston Society of Natural History, a member.

1867. Deutsche Astronomische Gesellschaft, Mitglied [commuted for life].

1868. New York Lyceum of Natural History, now the New York Academy of Sciences. Corresponding member.

1868. American Association for the Advancement of Science, Fellow.

1868. Cincinnati Literary Club, a member.

1869. Historical Society of Ohio, a member.

1871. American Philosophical Society of Philadelphia, a member.

1871. Philosophical Society of Washington, a member and founder. Treasurer and Editor of its *Bulletin*, 1891-1896. President, 1906.

1874. Oesterreichische Gesellschaft für Meteorologie (Vienna). Mitglied [commuted for life].

1874. American Metrological Society (New York), a member.

1875. Association Française pour l'avancement des Sciences, a member [commuted for life].

1875. American Geographical Society (New York). Corresponding member.

1876. Royal Astronomical Society (London), Fellow [commuted for life].

1879. National Academy of Sciences of the United States of America member. Hartley medalist, 1916.

1881. Victoria Institute of Great Britain (London), Associate of.

1881. New York Historical Society, Resident life member [commuted].

1882. American Forestry Association, a member.

1883. Deutsche Meteorologische Gesellschaft (Berlin). Korrespondierender Mitglied. [See 1892.]

1884. American Academy of Arts and Sciences (Boston). Associate fellow.

1884. New England Meteorological Society, a member. [Society dissolved in 1896.]

1887. British Association for the Advancement of Science. Corresponding member; also life member [commuted].

1888. National Geographic Society (Washington), a member [commuted to life].

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- 1890. American Historical Association, a member.
- 1891. New York Mathematical Society (*now* American Mathematical Society), a member.
- 1891. Royal Meteorological Society (London), a Fellow [later Honorary Fellow and Medalist].
- 1892. Deutsche Meteorologische Gesellschaft (Berlin). Ehren-Mitglied. [See 1883.]
- 1893. Deutsche Mathematische Vereinigung (Munich). Mitglied [commuted for life].
- 1894. Columbian Historical Society (Washington), a member.
- 1895. Société Météorologique de France, a member [commuted for life].
- 1896. Connecticut Historical Society (Hartford). Corresponding member.
- 1897. Societa Meteorologia Italiana (Turin), a member.
- 1898. Washington, D. C., Academy of Sciences, a member.
- 1898. American Institute of Electrical Engineers (New York). Associate member.
- 1899. American Physical Society, a member.
- 1900. Astronomical and Astro-physical Society of America, a member.
- 1902. Carnegie Institution of Washington: Chairman of the Committee of Advisors in Meteorology [temporary position; abolished in November, 1902].
- 1902. Geographical Society of Philadelphia, a member.
- 1905. Association of American Geographers.
- 1913. Seismological Society of America.

MEMBERSHIP IN CLUBS

- Cosmos Club, Washington, D. C., Feb. 5, 1883-Dec. 31, 1884.
- Harvard Club of Washington, 1900-1915.
- Washington Chapter Associate Alumni, College of the City of New York.

DELEGATE TO IMPORTANT CONVENTIONS, ETC.

- 1882. U. S. Signal Service delegate to American Forestry Congress at Cincinnati.
- 1884. U. S. Signal Service delegate to the Electrical Conference at Philadelphia.
- 1884. United States delegate to the International Meridian and Time Standard Congress at Washington.
- 1886. Columbian University (Washington) and Pres. J. C. Welling's delegate to 250th Anniversary of Harvard College.
- 1891. U. S. Weather Bureau associate delegate to 2d International Meteorological Conference at Munich.

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- 1896. Delegate of U. S. Weather Bureau, Columbian University, Kelvin's Baltimore Class of 1884, Kelvin Jubilee (Glasgow).
- 1900. United States delegate to International Congress of Physicists at Paris.
- 1901. College of the City of New York delegate to Bi-centennial of Yale University.
- 1904. U. S. Weather Bureau delegate to inauguration of C. S. Howe as President of the Case School of Applied Science.

DECORATIONS, ORDERS, MEDALS, AND PRIZES

- 1857. Free Academy of the City of New York: Ward Medal in Chemistry [established in 1853]. (Bronze.) Burr Medal in Mathematics [established ? in 1853]. (Silver.)
- 1886. H. H. Warner (Rochester, N. Y.). Medal for Scientific Discovery (gold) for his "Red Light Essay;" see Amer. Metr'l. Jour., April, 1889, 5: 529-544; also *ibidem*, v. 1, p. 454, and v. 3, p. 53.
- 1889. French Republic, Ministry of Public Instructions: "Officier d'Académie."
- 1901. Yale University, bi-centennial medal inscribed, Universitat Yalensis, A. D., MDCCCCI, concelebrat Collegium Yalense, A. D., MDCCI, conditum. (Bronze.)
- 1906. American Philosophical Society (Philadelphia) Franklin medal, inscribed: "Medal struck by the United States Congress to commemorate the 200th anniversary of the birth of Benjamin Franklin (1706-1790). (Bronze.)
- 1907. College of the City of New York: A. Werner memorial, inscribed: "To commemorate fifty years of service at the College of the City of New York. June, 1907. Adolph Werner, Scholar, Teacher, Friend." (Bronze.)
- 1912. Royal Meteorological Society of London: Symons Memorial Medal. (Gold.)
- 1912-13. Franklin Institute (Philadelphia): Longstreth Medal of Merit for his paper, "The Obstacles to the Progress of Meteorology." [See Jour. Franklin Instit., Feb., 1914, 177: 250.] (Silver.)
- 1916. U. S. National Academy of Sciences: Marcellus Hartley Memorial Medal "for eminence in the application of science to the public welfare." (Gold.)

EDITOR FOR METEOROLOGY IN OTHER THAN GOVERNMENT PUBLICATIONS

- 1872-79. Annual Record for Science and Industry (Harper & Bros.). Appleton's New Encyclopedia.
- 1892-94? Johnson's New Encyclopedia.
- 1900-02. New International Encyclopedia (Dodd, Mead & Co.), 1st ed.
- 1913-14. New International Encyclopedia (Dodd, Mead & Co.), 2d ed.

- 1904-13. Encyclopedia Britannica, 9th ed.
 Encyclopedia Britannica, 10th ed.
 Encyclopedia Britannica, Yearbook "1913."
 1889. Century Dictionary, 1st ed. ?
 1905. Century Dictionary.
 1908-9. Webster's New International Dictionary [1st ed.].

ASSOCIATE EDITOR, ETC.

- 1892-1896. American Meteorological Journal, Ann Arbor and Boston.
 1904-1916. Beiträge zur Physik der freien Atmosphäre, Strassburg and Leipzig.

SELECTED BIBLIOGRAPHY

1. Solutions of problems in the Mathematical Monthly. American Mathematical Monthly, Cambridge, 1859.
2. Solutions of the general equations of second degree. (Mémorial for the degree of A. M., New York City Free Academy, 1860.)
3. The transparency of the earth's atmosphere. Amer. Jour. Science, New Haven, 1864, 2nd series, 38, 28-31.
4. The computation of parabolic orbits; Brünnow's method. Amer. Jour. Science, New Haven, 1864, 2nd series, 38, 79-81.
5. The annual parallax of Sirius from observations at the Cape of Good Hope. Monthly notices, Roy. Astron. Soc., 1866.
6. On the distribution of nebulae in space. Monthly notices, Roy. Astron. Soc., May, 1867.
7. The Repsold portable vertical circle. Amer. Jour. Sci., New Haven, 1867, 2nd series, 43, 207-216, 309-315.
8. Dorpat and Pulkova. Annual Report of the Smithsonian Institution, 1867, pp. 370-390.
9. The portable transit instrument in the vertical of the pole star. *Translated* from the original memoir of Wm. Döllner. With appendix by Cleveland Abbe. U. S. Hydrographic Office, Washington, 1870, p. 8.
10. Inaugural report, 30th June, 1868, of the Director of the Cincinnati Observatory. *Reprinted* in the First Annual Report of the Cincinnati Observatory, Cincinnati, Ohio, May 1, 1869.
11. Circular inviting the formation of the Cincinnati or Western Meteorological Association. In Cincinnati daily papers of July 1, 1868.
12. The Cincinnati Observatory. (Letter to C. A. F. Peters, July 8, 1868.) Astronomische Nachrichten, No. 1707, 1868, 72, 43-44.
13. The resuscitation of the Cincinnati Observatory. Proc., Amer. Assoc. Adv. Sci., Chicago, 1868, 18, 172-174.
14. The meridian line of Ironton, Lawrence Co., Ohio. Ironton register, December, 1868.

15. Determination of the longitude of Ironton, Ohio. *Colton's Journal of Geography*, April, 1869, 1, 59-60. (Also in *Cincinnati Commercial*, Dec. 10, 1868.)
16. Memorial to the General Assembly of the State of Ohio: On the county meridian lines and State Surveys: Remonstrating against the proposed law authorizing changes in old monuments. Written, March 5, 1869. Printed March 6, 1869, by State Assembly officially. Columbus, Ohio, March, 1869.
17. Fort Ancient, Warren County, Ohio, Past and Present. *Cincinnati Commercial*, June 29 (?), 1869. *American Naturalist*.
18. Annual Report of the Director of the Cincinnati Observatory, May 1st, 1869, Cincinnati, 1869.
19. Results of hourly meteorological observations at Cincinnati Observatory. In the *Weekly Bulletin of the Cincinnati Observatory*, Cincinnati, July, 1869 to May, 1870.
20. Weekly reports on the activity of the observatory. *Weekly bulletin*, Cincinnati Obsy., Cincinnati, July, 1869, to May, 1870.
21. On Storm Warnings. An editorial in the *Chicago Evening Journal* of August 16 or 17, 1869.
22. Letter to Le Verrier at Paris, proposing international exchange of weather telegrams. *Bulletin hebdomaire de l'association scientifique de France*, August 15, 1869, t. 6, p. 100.
23. First Weather Bulletin for the Cincinnati Chamber of Commerce. Cincinnati, Ohio, September 1, 1869.
24. Weather Bulletins of the Cincinnati Observatory for the Cincinnati Chamber of Commerce. Cincinnati, O., Sept. 1 to Dec. 1, 1869. [Daily weather telegrams and predictions.]
25. Astronomical tables for the Annual Almanac, 1870, of the Cincinnati Gazette. Cincinnati, 1869.
26. Telegraph cipher code for the use of the Weather Bulletin of the Cincinnati Observatory. Cincinnati, Nov. and Dec., 1869.
27. Weather Bulletin of the Western Union Telegraph Co., compiled at the Cincinnati Observatory, Cincinnati, O., Dec., 1869, to May, 1870. [Daily weather telegrams without predictions.]
28. Storm predictions. Letter of January 7, 1870. "The Bureau," Chicago, Feb., 1870, 1, 132.
29. Note on Climatology. Statistical Report of the Secretary of State of Ohio, for 1869. Columbus, 1870, pp. 167-169. [Written in Feb., 1870.]
30. On standard city time. An editorial in the *Cincinnati Commercial*, March —, 1870.
31. The Greenwich Observatory. Our monthly (C. L. Thompson, Editor). Cincinnati, May, 1870.
32. A point in Egyptian chronology. *Monthly Notices*, Royal Astron. Soc., London, 1871.
33. Annual Report of the Director, Cincinnati Observatory, June 4, 1870. Cincinnati, 1870.

34. Latitude and longitude of Cincinnati. *Commercial Tribune*, Cincinnati, Oct. 8, 1870; *Colton's Journal of Geography*, New York, Jan., 1871, 1, 92-93.
35. On the connection between terrestrial temperature and solar spots. *Amer. Jour. Sci.*, New Haven, 3rd series, 1870, 1, 345-347; *Nature*, London, June 15, 1871, No. 85, 4, 123.
36. Tri-daily weather predictions, U. S. Signal Service (beginning February, 1871). Washington, 1871, etc. [Published in the name of the Chief Signal Officer, being official work in his office.]
37. An historical note on the method of least squares. *Amer. Jour. Sci.*, New Haven, 3rd series, June 1871, 1, 411-415.
38. Suggestions as to the practical uses of meteorological reports and weather maps. Washington, 1871. 8°. 2nd Ed., 1871; 3rd Ed., 1871; Reprinted in *Annual Report, Chief Signal Officer for year ending June 30, 1871*, as paper 6, on pp. 83-109. Washington, 1871. 8°.
39. Historical notes on the systems of weather telegraphy, and especially their development in the United States. *Amer. Jour. Sci.*, New Haven, 3rd series, 1871, 2, 83-98.
40. Determination of the altitudes of Signal Service stations. Dated December, 1872. [50 copies for distribution.] *See Annual Report of the Chief Signal Officer for 1873*. Washington, 1873, p. 958.
41. Remarks on a table of balloon voyages. *Bull. Phil. Soc. of Washington*, 1871, 1, 38-39. [Analysis of 50 balloon voyages by S. A. King, aeronaut of Philadelphia.]
42. Table for the computation of relative altitudes. *Amer. Jour. Sci.*, New Haven, 1872, 3rd series, 3, 31-34.
43. Observations on the total solar eclipse of [August 7] 1869. *Amer. Jour. Sci.*, New Haven, 1872, 3rd series, 3, 264-267. *Nature*, London, 1872, 5, 367-368.
44. Remarks on the observations of auroras. *Bull. Phil. Soc. of Washington*, Feb., 1872, 1, 45.
45. Structure of the [solar] corona. *Nature*, London, Mar. 7, 1872, No. 123, 5, 367-368.
46. Charts, text, and tables showing some features of the climate of the United States: 1, Temperature of the coldest and warmest week; 2, Isobars and resultant wind movement; 3, Storm frequency. *In Walker's Statistical Atlas of the United States*. Washington, 1874. [Erroneously credited to Lieut. Jackson, under whom was working the draftsman who prepared Abbe's drawings.]
47. Table of differences between local and Washington time for Signal Service stations. *Annual Report, Chief Signal Officer for 1873*. Washington, pp. 960-962. ["My report in minutes and tenths was printed as minutes and seconds."]
48. Table of elevations of Signal Service stations and bench marks.

- Annual Report of the Chief Signal Officer for 1873. Washington, 1874, pp. 950-960.
49. Chronological list of auroras, November, 1871, to July, 1873. Annual Report of the Chief Signal Officer for 1873. Washington, 1874. Appendix 32, pp. 1098-1107. (Reprinted as Addendum to Greely's chronological list, in U. S. Signal Service Professional Paper No. 3. Washington, 1881, pp. 71-76. 4°.)
 50. Catalogue of auroras observed from 1776-1784 in Labrador. Amer. Jour. Science, New Haven, 1873, 3rd series, 6, 151-152.
 51. Nova Scotia cyclone of August, 1873. Annual Report, Chief Signal Officer for 1873. Washington, 1874, pp. 1025-1034, 6 charts. 8°.
 52. On the dissipation of electricity in gases, by Prof. Demetrieff Bouboulieff. Translation by Cleveland Abbe. Amer. Jour. Sci., Feb., 1874, 3rd series, 7, 118-130.
 53. On the laws governing the movement of storm centers. *Abstract.* Bull. Phil. Soc., Washington, June, 1874, 1, 100-101.
 54. On the positions of the planes of certain nebulae. *Abstract.* Bull. Phil. Soc., Washington, June, 1874, 1, 119.
 55. On the aurora of April 7, 1874, with a chart. Annual Report of the Chief Signal Officer for 1874. Washington, 1874, pp. 383-385, 1 map.
 56. General remarks on the comet. New York *Herald*, July, 1874. On the possibility of the tail enveloping the earth, with the possible result to climate.
 57. Observations on the tail of Coggia's comet (comet No. 3 of 1874). [June and July, 1874.] Dated Oct. 1, 1874. *Astronom. Nachrichten*, 1874, Bd. 84, Col. 353-366.
 58. Letter to Dr. Julius Hann on Ferrel's theory, dated December 29, 1874. *Ztschr. Oesterr. Gesellschaft f. Met.*, Wien, 1875, 10, 93-94. [This letter drew the attention of Hann, Koeppen, and Sprung to Ferrel's works.]
 59. The very much extended nebulae of Sir. John Herschel's "General Catalogue." Amer. Jour. Sci., New Haven, 3rd series, Jan., 1875, 9, 42-46.
 60. On the meteorological theorem of Espy, by Faye. Translated for Journal, Franklin Institute, Philadelphia, Nov., 1875, 70, 348-354.
 61. On the laws of adhesion: Apparent adhesion, by Stefan. Translation of a notice of Stefan's work. Jour. Franklin Inst., Philadelphia, April, 1875, 3rd series, 70, 121-125.
 62. The Bulletin of International Simultaneous Meteorological Observations. Editor and author, 1875-89. [This great organization was official work, published in the name of the Chief Signal Officer.]
 63. The aurora of April 7, 1874. Second Report. In Annual Report of the Chief Signal Officer for 1875. Washington, 1875, pp. 367-374.

64. The aurora of April 7, 1874. Third (final) Report. In Annual Report of the Chief Signal Officer for 1876. Washington, 1876, pp. 301-310.
65. Supplying omission in a closed survey. *The Analyst*, —, 1876, —.
66. (Wind tables relative to the movement of the sand dunes on the coast of North Carolina) in S. T. Abert, "Report on the Survey," Washington, Feb. 21, 1876.
67. Report of the Committee to Collect Information relative to the Meteor of December 24, 1873. *Bull. Phil. Soc.*, Washington, April, 1877, 2, 139-161.
68. Instructions to meteorological observers on the Schooner *Florence*, on the Howgate expedition to Cumberland Gulf. Washington, 1877. (These instructions included a method for determining cloud heights by means of a small balloon.)
69. O[rmsby] M[cKnight] Mitchell's observations of double stars. *Monthly Notices Royal Astron. Soc.*, London, 1877.
70. Short Memoirs on Meteorological subjects. *Translation*. Annual Report of the Smithsonian Institution for 1877. Washington, 1878. 8°, pp. 377-478.
71. On the connection between meteorological phenomena and locust migration. In First Annual Report, U. S. Entomological Commission for 1877. Washington, 1878. 8°, pp. 203-211. (U. S. Geological Survey publication.)
72. The influence of temperature on the hatching of locust eggs. In First Annual Report, U. S. Entomological Commission, for 1877. Washington, 1878. 8°, pp. 423-432. [See also Riley in Second Annual Report, etc., Washington, 1879. 8°, pp. 136-140.]
73. Report of the Chief Signal Officer, predicting the general probabilities for fair observing weather on May 8, 1878, for the transit of Mercury; and on July 28, 1878, for the total solar eclipse. (Dated April, 1878. Lithographed communication to the U. S. Naval Observatory and to the daily press.) [Annual Report, Chief Signal Officer for 1880. Washington, 1881. 8°, pp. 813-818, "Document No. II."]
 "This was the first time, to my knowledge, that such extensive long-range forecasts were made and the average verifications were remarkably satisfactory," C. A.
74. Signal Service observations of the transit of Mercury, May 8, 1878. *Monthly Weather Review*, May, 1878. Also Annual Report Chief Signal Officer for 1879. Washington, 1879, pp. 780-782.
75. Present state of meteorology. In *Appleton's Annual Cyclopedia* for 1878. New York, Vol. 3, pp. 537-545.
76. Report on observations of the transit of Mercury of May 6, 1878. Annual Report, Chief Signal Officer for 1879. Washington, 1880, pp. 780-782.

77. (First) Report on standard time by Cleveland Abbe, Chairman of the special committee of the American Metrological Society. Proc. Amer. Metrol. Soc. for May, 1879, New York, 1880, 2, 17-44. [The reports of the above committee appeared in Proc. Amer. Metrol. Soc., New York, 1879, 2, 17-29, 174-179, 231-233, 308-311; do., 1882, 27-30; do., 1883, 4, 22-24; do., 1884-5, 5, 52-82.]
78. Conditions on which the Chief Signal Officer co-operates with others in the maintenance of a public standard time ball. Proc. Amer. Metrol. Soc., New York, 1879, 2, 181-183. Reprinted in same, 1883, 4, 53, and as Circular No. 2 of the American Metrological Society. In Annual Report of Chief Signal Officer for 1881. Washington, 1882.
79. On standard time. Science News, June 14, 1879.
80. The hatching and migration of grasshoppers. American Naturalist, October, 1880.
81. Climate and diseases. Bulletin, National Board of Health. July 17, 1880, No. 3, 2, 445-447.
82. Reports and observations on the total eclipse of the sun, July 29, 1878, as filed in the office of the Chief Signal Officer of the Army. Annual Report, Chief Signal Officer for 1880. Washington, 1881. Accompanying papers, No. 48, pp. 809-983, 33 Figs. 8°. (Reprinted as Professional Papers, U. S. Signal Service, No. 1. Washington, 1881. 4°.)
83. (Second) Report on standard time . . . Dec. 16, 1880. Proc. Amer. Metrol. Soc., Vol. 2, 174-177.
84. Report of the Board on Signal Service barometric standard, with appended Tables. Dated Jan. 24, 1881; with corrections dated July 30, 1881. Annual Report, Chief Signal Officer for 1881. Washington, 1882. Appendix No. 59, pp. 1126-1137. 8°.
85. Report of the Board on Signal Service thermometric standard. Dated Feb. 14, 1881. Annual Report of Chief Signal Officer for 1881. Washington, 1882. Appendix No. 58, pp. 1121-1125.
86. Report of the Board on monthly constants for reduction of the barometer to sea level. Dated Feb. 18, 1881. Report of Cleveland Abbe communicating the desired monthly constants, dated May 14, 1881. In Annual Report, Chief Signal Officer for 1881. Washington, 1882. Appendix No. 62, pp. 1185-1189. 8°.
87. On indexing meteorological publications and observations. Papers and Proceedings, Fourth General Meeting, American Library Association at Washington and Baltimore, Feb. 9-11, 1881. Boston, 1881, pp. 60-61.
88. Circulars of the American Metrological Society: Standard Time Circular No. 1, dated Mar. 15, 1881. See Proc. Amer. Metrol. Soc., New York, 2, 177-180, and 4, 52. (Written by C. A. for the use of the Amer. Metrol. Soc.; signed and published by its president, F. A. P. Barnard.)

89. Letters and circulars to the governors of the different States, inviting the establishment of State weather services; signed by W. B. Hazen, Chief Signal Officer. (*See Annual Report, Chief Signal Officer for 1881. Washington, 1882. Appendix No. 73, pp. 1262-1263, and Annual Report for 1882. Washington, 1883. Appendix No. 58, pp. 761-770.*)
90. (Third) Report on standard time, etc., May, 1881.
91. Preamble and resolutions [on an International Time System] submitted by Gen. W. B. Hazen to the International Geographical Congress at Genoa, September 1, 1881. *Proc. Amer. Metrol. Soc., Vol. 2, 289. Also in Proceedings of the International Geographical Congress. Venice, 1881. Also in Annual Report, Chief Signal Officer for 1881. Washington, 1882. Appendix No. 69, p. 1249.*
92. Preliminary list of meteorological problems proposed to be submitted to scientists at large for investigation and competitive essays; with a view to publication among the Professional Papers of the Signal Service (dated May-June, 1881). *Annual Report, Chief Signal Officer for 1881. Washington, 1882. Appendix No. 70, pp. 1257-1258.*
93. Preliminary list of meteorological problems and studies proposed to be submitted to the officers and enlisted men of the Signal Service for voluntary action and report, with a view to publication among the Professional Papers of the Signal Service. (Submitted May, 1881.) *Annual Report, Chief Signal Officer for the year 1881. Washington, 1882. Appendix 72, pp. 1259-1261.*
94. "L'Actinomètre Arago-Davy," by Albert Levy. *Translated by C. Abbe. In Annual Report of Chief Signal Officer for 1881. Washington, 1882. Appendix No. 64, pp. 1191-1200. 8°.*
95. "Actinométrie," by Aymonnet. *Translated by C. Abbe. In Annual Report, Chief Signal Officer for 1881. Washington, 1882. Appendix No. 65, pp. 1200-1216. 8°.*
96. (Fourth) Report of standard time. Dec. 24, 1881.
97. An account of the progress in meteorology and allied subjects in the years 1879-1881. *Ann. Rept. Smithsonian Instit., 1881. Washington, 1883 [reprinted as Smiths. Public., No. 484. Washington, 1883. 2 vols., 121 p. 8°.]*
98. Lectures on instruments and methods. (Abstract of 20 lectures at Fort Myer, Va.) *Annual Report, Chief Signal Officer for 1882. Washington, 1883. Part I, Appendix 3, pp. 97-103. 8°.*
99. "Climate and tree growth" (by title), before First American Forestry Congress, Cincinnati, April 25, 1882. [Based on abstract of his measurements of Hough's tree sections.]
100. (Fifth) Report of the Committee on Standard Time, May, 1882. *Proc. Amer. Metrol. Soc., 3, 27-30.*
101. Joint resolution of the U. S. Senate and House of Representatives authorizing an international conference on standard me-

- ridian and time. [Drawn up by C. A.; presented by General Hazen, C. S. O., in May, 1882, to Hon. R. P. Flower, M. C. from New York, Chairman of Committee. Passed.] *See Proc. Amer. Metrol. Soc.*, 3, 5-6.
102. Account of the progress in Meteorology in the years 1880, 1881, and 1882. Annual Report, Smithsonian Institution, 1882 (Washington, 1885), pp. 365-457.
 103. On determining the temperature of the air. (Abstract.) *Bull. Phil. Soc.*, Washington, 1884, 6, 24-26.
 104. Course of study in meteorology for use at scientific schools. (June, 1883?) Annual Report of Chief Signal Officer for 1884. Washington, 1884. 8°, p. 75. [Transmitted to Brown University.]
 105. (Sixth) Report of the Committee on Standard Time. (December, 1883.) *Proc. Amer. Metrol. Soc.*, 4, 22-24.
 106. Account of the progress in Meteorology in the year 1883. Annual Report, Smithsonian Institution, 1883. Washington, 1884. 8°, pp. 483-569.
 107. Signal Service plans as to standard time. *In New York Herald*, January (6 ?), 1884. [This official interview with a reporter of the *Herald* was written out by Cleveland Abbe at General Hazen's request. The newspaper article led the then Secretary of the Navy to move the then Secretary of War to order General Hazen, C. S. O., to stop. *See Science*, New York, Sept. 8, 1905.]
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 109. On discrimination between disturbed and undisturbed magnetic observations. *Mittheil., Internationale Polar Commission*, 1884, Part 5, p. 198. [Recommendations prepared by C. A. for official use; forwarded by General Hazen, C. S. O., to the International Polar Commission for discussion at its Vienna meeting, April, 1884.]
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 b. "Organization of seismometric observations."
 c. "Methods of verifying weather predictions."
 d. "Barometry and thermometry."
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 121. Relation of the wind to meteorological measures: The disturbing influence of the wind on the observed barometric pressure and on the catch of the rain gage. Presented before the National Academy of Science, Boston, Nov. 9, 1886. (See Science, New York, 1886, 8, 449-450.)
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 124. Note on Fort Ancient, Ohio. Science, New York, 1887, 60, 34.
 125. William Babcock Hazen (Biographical notice). Science, New York, 1887, 9, 331-334; Popular Science Monthly, New York, 1887, 31, 112-117; Nature, London, 1886-87, 35, 541-543.
 126. The general bibliography of meteorology and terrestrial magnetism. Presented to the Manchester meeting of the British Association for the Advancement of Science, August, 1887. See An-

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127. Treatise on Meteorological Apparatus and Methods. Dated Oct., 1887. Annual Report, Chief Signal Officer for 1887. Part 2, being Appendix 46. Washington, 1888. 8°, 392 pp., 98 figs. [Notes were added to the proof-sheets up to August, 1888.]
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180. A course of instruction in meteorology. Letter of Oct. 14, 1893, to Seth Low, president of Columbia University. See *Science*, New York, Nov. 29, 1895, 2, 709-714, where its title reads "Meteorology in the University."
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1894. (Dated Feb. 22, 1894.) *See Amer. Met'l Jour.*, May, 1894, 11, 1-6.
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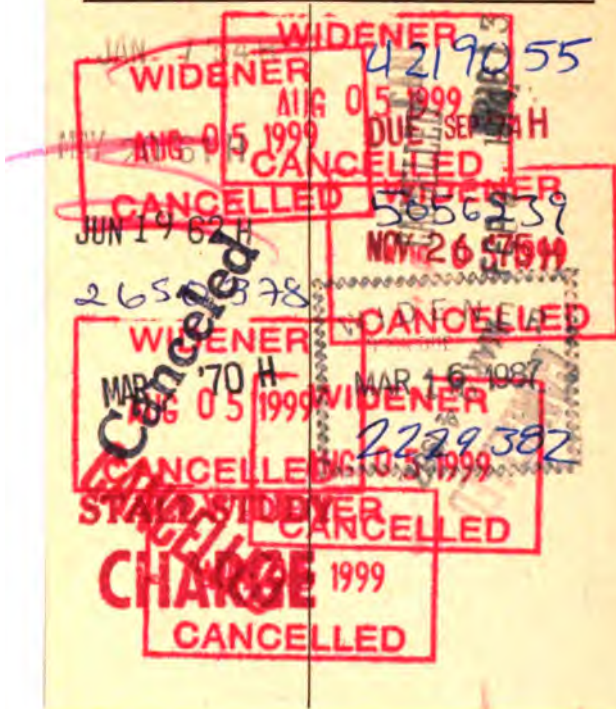
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